PROCEEDINGS

OF THE

Liverpool Geological Society.

SESSIONS XXX.—XXXIII.

1888—92.

EDITED BY THE HON. SECRETARY.

(The Authors, having revised their own Papers, are alone responsible for the facts and opinions expressed in them.)

VOLUME VI.

LIVERPOOL:
C. TINLING AND CO., PRINTERS, VICTORIA STREET.

1892.

CONTENTS.

PROCEEDINGS

OF THE

Liverpool Geological Society.

SESSION THE THIRTIETH,

1888-9.

EDITED BY W. HEWITT, B.Sc.

(The Authors, having revised their own Papers, are alone responsible for the facts and opinions expressed in them.)

PART 1. VOL VI.

LIVERPOOL

C. TINLING AND CO., PRINTERS, VICTORIA STREET.

1889.

PROCEEDINGS

OF THE

Liverpool Geological Society.

SESSION THE THIRTIETH,

1888-9.

EDITED BY W. HEWITT, B.Sc.

(The Authors, having revised their own Papers, are alone responsible for the facts and opinions expressed in them.)

PART 1. VOL. VI.

LIVERPOOL

C. TINLING AND CO., PRINTERS, VICTORIA STREET.

1889.

OFFICERS, 1888–9.

President:

HENRY C. BEASLEY.

Vice-President:

F. P. MARRAT.

Ex-President:

G. H. MORTON, F.G.S., F.R.G.S.I.

Honorary Treasurer:

EDWARD M. HANCE, LL.B.

Honorary Librarian:

EDWIN FOSTER.

Honorary Secretary:

WILLIAM HEWITT, B.Sc.

Council:

J. J. FITZPATRICK.
REV. S. GASKING, B.A., F.G.S.
OSMUND W. JEFFS.
C. RICKETTS, M.D., F.G.S.
T. MELLARD READE, C.E., F.G.S.

LIST OF SOCIETIES, ETC., TO WHICH THE PROCEEDINGS OF THE LIVERPOOL GEOLOGICAL SOCIETY ARE SENT.

*(Publications have been received in exchange during the Session from those marked *)*

*Academy of Natural Sciences, Philadelphia.
Advocates' Library, Edinburgh.
*Belfast Naturalists' Field Club.
Birkenhead Free Public Library.
* ,, Literary and Scientific Society.
Birmingham Philosophical Society.
British Museum.
British Museum (Natural History) Geological Department.
*British Association for the Advancement of Science.
*Bristol Naturalists' Society.
Bodleian Library, Oxford.
*Boston Society of Natural History, U.S.
*Chester Society of Natural Science.
*Colorado Scientific Society.
Dudley and Midland Geological and Scientific Society.
*Essex Naturalists' Field Club.
Editor of "Geological Record."
,, "Nature."
,, "Geological Magazine."
,, "Science Gossip."

Ertborn, Le Baron O. Van, Anvers, Belgique.
*Geological Society of Edinburgh.
*Geological Society of Glasgow.
*Geological Society of London.
*Geological Society of Manchester.
Geological Society of Norwich.
*Geological Society of Australasia, Melbourne.
*Geological Survey of the United States.
Geological Survey of India.
Geological Survey of Canada.
*Geologists' Association, London.
*Glasgow Philosophical Society.
*Imperial Academy of Naturalists, Halle, Prussia.
*Leeds Philosophical and Literary Society.
*Leeds Geological Association.
Liverpool Athenæum.
,, Chemists' Association.
* ,, Free Public Library.
* ,, Geological Association.
,, Literary and Philosophical Society.
,, Lyeeum Library.
* ,, Philomathic Society.
* ,, Engineering Society.
* ,, Astronomical Society.
* ,, Science Students' Association.
*L'Universite Royal de Norvége, Christiana.
*Manchester Association of Engineers.
*Manchester Literary and Philosophical Society.
Minnesota Academy of Natural Science, Minneapolis, U.S.
Musée Royal D'Histore Naturelle de Belgique.
Museu Nacional, Rio de Janeiro.
Museum of Practical Geology, Jermyn Street, London.
*North of England Institute of Mining and Mechanical Engineers.
*New York Academy of Sciences.
Owens College, Manchester.

Patent Office Library, 25, Southampton Buildings, Chancery Lane, London, W.C.
*Royal Dublin Society.
*Royal Geological Society of Ireland, Dublin.
Royal Society, London.
*Smithsonian Institution, Washington. U.S.
*Société Geologique de Belgique, Liege.
*Société Geologique du Nord, Lille.
*Société Impériale des Naturalistes de Moscow.
*Société Royale Malacologique de Belgique.
*Sociedade de Geografia de Lisbon.
*Toscana Societa di Scienza Naturali.
*University Library, Cambridge.
University College, Bangor.
,, ,, Liverpool.
*Warwickshire Natural History and Archæological Society.
Watford Natural History Society.
Wagner Free Institute of Science, Philadelphia.
Woodwardian Museum, Cambridge.
Yorkshire Geological and Polytechnic Society.

PROCEEDINGS

OF THE

LIVERPOOL GEOLOGICAL SOCIETY.

SESSION THIRTIETH.

OCTOBER 9TH, 1888.

THE PRESIDENT, H. C. BEASLEY, ESQ., in the Chair.

M. A. DAUBRÉE and Dr. A. F. RENARD were elected Foreign Corresponding Members, and Mr. W. GOODALL an Ordinary Member.

The Officers and Council for the ensuing year were elected.

The President read his ANNUAL ADDRESS.

NOVEMBER 13TH, 1888.

THE PRESIDENT, H. C. BEASLEY, ESQ., in the Chair.

Dr. A. HEIM, Baron F. VON RICHTHOFEN, Major-Gen. VON KOKSCHAROW, Prof. J. VILANOVA-Y-PIERA, were elected Foreign Corresponding Members.

The Hon. Treasurer submitted his Statement of Accounts.

The following paper was read :—

LOCAL HISTORICAL CHANGES ON THE SURFACE OF THE LAND IN AND ABOUT LIVERPOOL.

By Sir J. A. PICTON, F.S.A.

DECEMBER 11TH, 1888.

THE PRESIDENT, H. C. BEASLEY, ESQ., in the Chair.

The following papers were read :—

THE PERMIAN CONGLOMERATE AND OTHER PALÆOZOIC ROCKS TO THE NORTH OF MORECAMBE BAY.

By J. J. FITZPATRICK.

FURTHER NOTES ON THE STANLOW, INCE, AND FRODSHAM MARSHES.

By G. H. MORTON, F.G.S.

JANUARY, 8TH, 1889.

THE PRESIDENT, H. C. BEASLEY, ESQ., in the Chair.

The following papers were read :—

RECENT AND FOSSIL CRINOIDS.

By F. P. MARRAT.

SOME BORINGS AND THE BASE OF THE NEW RED SANDSTONE IN THE NEIGHBOURHOOD OF LIVERPOOL.

By A. TIMMINS, C.E.

NOTES ON SOME BASALTIC DYKES NEAR AROS, MULL.

By J. LOMAS, Assoc. N.S.S.

FEBRUARY 12TH, 1889.

THE PRESIDENT, H. C. BEASLEY, ESQ., in the Chair.

The following paper was read :—

THE VYRNWY VALLEY; ITS GEOLOGICAL AND GLACIAL HISTORY.

By Sir J. A. PICTON, F.S.A.

MARCH 12TH, 1889.

THE PRESIDENT, H. C. BEASLEY, ESQ., in the Chair.

The following paper was read :—

SLICKENSIDES AND NORMAL FAULTS.

By T. MELLARD READE, C.E., F.G.S.

APRIL 9TH, 1889.

THE PRESIDENT, H. C. BEASLEY, ESQ., in the Chair,

The following papers were read :—

SOME FAULTS EXPOSED IN SHAFTS AND BORINGS IN THE COUNTRY AROUND LIVERPOOL.

By G. H. MORTON, F.G.S.

EXAMINATION OF VOLCANIC ROCKS OF THE ISLE OF MAN.

By E. DICKSON, F.G.S., and P. HOLLAND, F.C.S.

FIELD MEETINGS were held during 1888, at—

Isle of Man.
Dudlow Lane Well Boring.
Flaybrick Hill and Lingdale Quarry.
Geological Museum, Owens College, Manchester.
South Coast of Isle of Man.
Ince, Stanlow, and Ellesmere.
Ingleton.
Spring Hill Well, Oxton.

The Liverpool Geological Society, *in Account with E. M. HANCE, Treasurer.*

Dr. SESSION, 1887-8. **Cr.**

Dr.	£	s.	d.
To Balance in hand, October 11th, 1887	14	19	3
,, Subscriptions received for current Session	30	9	0
,, Arrears from previous Sessions	13	2	6
,, Special Donations to Library	1	0	0
,, Sale of "Proceedings"	3	2	0
	£62	12	9

Cr.	£	s.	d.
By Rent to Oct. 1st, 1888	5	0	0
,, E. Doling (Teas, &c.), for Session 1886-7	5	15	0
,, Ditto, Session 1887-8	6	9	6
,, Hon. Secretary's Expenses, 1886-7	3	18	10
,, Hon. Secretary's Expenses, 1887-8	2	16	7
,, Hon. Librarian's Expenses, 1886-8	1	7	7
,, Hon. Treasurer's Expenses, 1886-8	0	2	10
,, Excursion Expenses	0	6	6
,, Tinling & Co.	20	15	0
,, Subscriptions to "Geological Magazine," 1886-7	1	7	0
,, ,, "Geological Record"	0	10	10½
,, Balance in hand	14	3	0½
	£62	12	9

Audited and found correct,

J. LOMAS.
E. DICKSON.

PRESIDENT'S ADDRESS.

My predecessors in this chair have of late years devoted the main portion of their addresses to the exposition of certain subjects, to the investigation of which they have given many years of observation and research. I propose, however, on the present occasion to depart from this custom, and to make some suggestions with reference to investigations that may, with very great advantage to our science, be carried on by members of this Society, and for which facilities of observation are readily offered in the immediate neighbourhood.

We have many members from whom the Society seldom hears a word except in the form of a question, and it is much to be regretted that the actual readers of papers are so few. A man who takes an intelligent interest in Geology generally, and has acquired some sound elementary knowledge of its main facts and principles, has added a new field of intellectual pleasure to his existence. He has extended the limit of his mental vision into the past to a distance not before thought of, and he has filled with life and speech what had before been to him dull inanimate objects, mere masses of brute matter. Further, he has presented to him problems great and small of equal interest with those of metaphysics, which have fascinated great minds in all ages; but geological problems, though perplexing, are, unlike those of metaphysics, capable in the end of certain and

absolute solution. Some return for this is, I think, due to our science.

If any one takes up a particular subject—not to the exclusion of all others, but as one demanding his principal attention—and inquires as each fact or suggestion comes before him, "How does this bear on what I have in hand?" he cannot fail before long to meet with something worth recording, whether it be an observed fact or a new view of something already known. In any such case, I would say, bring it before your fellow members that they may have the benefit of it. Bring it as it were to the light of day, that it may be fully seen in all its bearings and its correctness tested.

We have most of us no doubt heard the opinion expressed by outsiders that "there is no geology about Liverpool," following the popular idea that geology consists in fossil hunting. That our district does not present very promising material for palæontological research we all know; but for the study of physical geology and the investigation of many problems connected with it we are situated quite as well as, if not better than, most other places. This Society has in the past recognised this, as any one looking through the volumes of its Proceedings will readily see, and it is to be hoped that the reputation it has already earned will be upheld and extended by the exertions of present and future members.

There are in this district two sets of strata particularly well developed, and to investigations connected with these I would now proceed to draw your attention.

There are the Glacial and Post-Glacial deposits, and the phenomena connected with them; and secondly, the great Triassic division, all the members of which are

to be seen, and, with the exception of the red marl, very fully developed, within a few miles of this room.

To any one inquiring into questions affecting either of these formations, every opening in the ground, if only for the making of a sewer or foundation of a building, will be found of interest.

The Glacial period has left two sets of records of its existence in this district. The one the deposits of boulder clay and sand; the other the striated rock surfaces, the patches of sand and angular fragments of local rocks, and crumpling of softer strata often associated with them.

With regard to the boulder-clay of this district, geologists are tolerably well agreed as to its origin, but there is still work to be done in tracing the boulders contained in it to the parent rock, in addition to the work that has already been so ably done by Mr. Mackintosh and others, and recorded in Q.J.G.S., p. 425, vol. 35, and elsewhere.

With regard to the beds and pockets of sand that are found in the boulder-clay, there is yet room for a great deal of work. That these beds divide the boulder-clay into an upper and lower division is now generally admitted, though there is still some doubt whether the division can hold good over more than a very limited area. However this may be, the deposits of sand point to conditions quite different from those resulting in the deposit of the boulder-clay. Whilst at times extending as regular beds of sand and gravel for some distance, they often consist of patches of pure sand free from boulders or shells, contained in pockets of most irregular shape. It has been suggested that in the case of pockets and lenticular patches, they may have been dropped as frozen masses from bergs, but this is hardly probable

except in a few instances. As I have said, they point to very different conditions of deposit from those resulting in the boulder-clay, although from their position they appear to have been contemporaneous.

An excellent exposure of these sands was made during the construction of the Cheshire lines extension between Garston and Hunt's Cross, and was described by Mr. T. M. Reade, F.G.S., in our Proceedings—vol. 3, pt. I.; also by Mr. C. E. De Rance, F.G.S., in his "Geology of the Country round Southport."

The examination of these sands, and the collection of facts regarding them, their relation to the clays above and below, and the differences between the upper and lower clay, present a field for most useful work.

Owing to the soft nature of the rocks in our district glaciated surfaces are of only occasional occurrence, but generally when the top bed of rock happens to be a hard one, and protected by a coating of clay, the surface will be found to show traces of glaciation. It is of great importance that wherever this is noticed the direction of the striæ should be accurately recorded, and, if possible, a rubbing should be taken, the compass bearing being carefully marked thereon before removing the paper from the rock, thus preserving a correct and permanent record. It is also desirable to notice if there is anything tending to denote the direction of the movement of the ice along the striæ—say whether from north to south or from south to north.

I would impress on members the necessity for making these observations at once whenever they meet with a fresh exposure, because if the exposure be artificial it will probably be only temporary, and if natural it will soon become weathered. A list of the glacial striæ in this neighbourhood, by Mr. G. H.

Morton, F.G.S., will be found in the Proceedings of this Society, Session 1876-7; a few others were recorded by me in another paper, Session 1884-5, and Mr. Aubrey Strahan, F.G.S., has recorded them over a larger area in the Q.J.G.S., vol. 42, part 269.

It will be noticed that the general direction of the striæ on the different exposures within half-a-dozen miles of the Exchange ranges within 15° on either side of 30° west of north. The greater part are within a much smaller range, although on most of the exposures there are a few striæ varying 10° or 15° from the average direction. In a few cases some striæ are recorded crossing the others at right angles. In one or two cases the striæ are practically quite parallel.

The best parallel set of striæ I have seen are those on the top of the hill at Wallasey, and they were suggestive of the steady movement of a great mass of ice; but at Poulton, on the same ridge, though at a lower level by some 50 feet, whilst preserving the same general direction, some of the striæ vary from it to an extent of 15 degrees, and the same may be said of those at the foot of Flaybrick Hill, at a still lower level, and on the top of Bidston Hill at a higher level than at Wallasey.

I have not seen any striæ at the bottom of hollows, they have all been on more or less convex surfaces of rock.

The striæ recorded at Runcorn, Appleton, and Farnworth have quite a different direction from those to which I have just referred, but on reference to a map it will be seen that they follow the direction of the valley of the river there.

I have not seen or heard of any trace of a terminal moraine in this district, but all accumulations I have

n
o
re
nt
er
n,

on
mit
litic
oul
r d

well
befor
l be s
to th
given
able a
their n
hilst he
ince the
reduced t
me writer
the first t
of further
pose his th
e whole dr
y carefully a
ty good agr
rkers ; but a

time.—Mr. T.
4, p. 291.

seen were such as might have been formed in hollows under moving ice. They are beds of angular fragments of rock from the immediate neighbourhood, mixed with sand. Instances of these, at Tranmere and elsewhere, have frequently been described to the Society, by Dr. Ricketts, and in the neighbourhood of Garston by Mr. Reade, in the paper before referred to. The same thing is very clearly seen at Poulton Quarry, which was visited by the Society some years ago. But perhaps the most instructive section is that at Moorhill, near Crosby, described and shewn to the Society by Mr. T. Mellard Reade,* where other glacial phenomena were also to be seen, viz.: the bending over, crumpling, and breaking up of the inclined strata and the striation of the rock all connected together.

The presence of patches of moraine matter would seem to point to land ice, but want of parallelism in the striæ looks more like floating ice as the agent.

Supposing the action of the floating ice, there is no necessity for the striæ at various levels being contemporaneous. If they were formed during a period of subsidence, each area soon after being striated would be covered with a protecting deposit of clay, and be preserved from further erosion. Or supposing the agency to have been land ice, the result would be the same if the action took place just where the glacier discharged itself into the sea as suggested in my paper.

Between the moraine matter and the lower boulder-clay there is every gradation to be seen. The disturbance of the lower beds of the boulder-clay and those beneath point, I think, to the grounding of icebergs, and the breaking up of the strata and formation of moraine matter is possibly due to this cause.

* Q.J.G.S., vol. 41, page 454.

For myself I am rather more inclined to believe in floating icebergs than I was when I read my paper on the subject—but it is still quite an open question.

The opinions that have been expressed and the theories advanced in this room, not to mention elsewhere, have been very various, and often apparently conflicting, but may they not, upon examination, be found to refer to different sets of phenomena? The time that has elapsed between the production of one set of phenomena and another now in close proximity to it may have sufficed for a great change of conditions, and this fact is very liable to be overlooked. I would therefore urge on members the collection of further data wherever and whenever possible.

The Post-Glacial deposits so well developed in our district have been so constantly before this Society for the last twenty years that it would be superfluous for me to draw the attention of members to them.

Additional interest has been given to them during the past year by the gallant and able attempt of one of our members* to grapple by their means with the question of geological time. Whilst he has conclusively shewn that the lapse of time since the deposit of the marine boulder-clay cannot be reduced to the comparatively small dimensions that some writers would allot to it, I am sure the author would be the first to acknowledge the desirability of the collection of further data, whether they may tend to support or oppose his theory.

The rate of erosion over the whole drainage area of many great rivers has been very carefully and accurately worked out, and there is a pretty good agreement in the results arrived at by various workers; but as regards the

* An Estimate of Post-Glacial time.—Mr. T. M. Reade. Q.J.G.S., vol. 44, p. 291.

rate of widening and deepening the valleys themselves at different points there still remains a very great deal to be done, and it is along this line that we must look for the most important results*.

Turning now to the older series of rocks I have mentioned and beginning at the base—the nearest points I think at which Permian rocks may be seen are near Whiston and St. Helens Junction; but the junction of the Permian and lower mottled sandstone has not been seen in the immediate neighbourhood. What might possibly be the junction of the two formations has been seen in a well section near St. Helens Junction, but, in the absence of fossils, it is very difficult to decide what the beds really are.

The undoubted Triassic rocks are known to rest at several points directly upon the Carboniferous.

A boring which it is reported is proposed to be made higher up the valley of the Mersey to search for saliferous beds in the Permian will be watched with great interest, but at present it is a very open question how far the Permian extends in this direction, whether it is represented by the beds now called Lower Bunter or is entirely absent in the immediate neighbourhood. There is a question whether certain beds farther east, classed as Permian, are not really part of the Carboniferous series. Were we able to see a distinct line of unconformability it would be easier to decide, but the constant occurrence of current bedding renders it very difficult to ascertain the true dip of the beds, unless they are seen in an extended section. Our Proceedings for Session 1881-2, contain a Paper† by Mr. G. H. Morton, which it would be well for any one taking up this question to attentively study.

* See Geikie's "Text-book of Geol.," 1st Edn., page 446.

† "On the base of the New Red Sandstone in the Country round Liverpool."

Mr. Irvine has described in other districts, beds supposed to be Permian that pass imperceptibly into the Bunter, but there seems to be a doubt as to their actual age. As investigation proceeds however, it points more and more to a gradual passage between the Permian and Triassic rocks, and it is worthy of notice that Mr. H. B. Woodward* amongst others has reverted to the old plan of classing together the Permian and Trias under the term New Red Sandstone or Poikilitic; whilst Mr. Jukes Browne † gets over the difficulty by calling the Permian, passage beds.

However much uncertainty there may be as to the relative importance of the physical break between the Carboniferous and the Permian and that between the latter and the Trias, there is little doubt amongst palæontologists as to the far greater importance of the latter.

Whilst an unconformity of strata indicates most certainly a great break and lapse of time, on the other hand an apparent conformity, the beds above being quite parallel to those beneath, does not prove the absence of a break in continuity of deposition or lapse of time.

The lapse of time indicated by a break in the geological record is naturally most difficult, if not impossible, to estimate. We do know, however, that a very long period elapsed between the deposition of the lowest bed of thé Trias and the beds where we find a sufficient number of organic remains to enable the palæontologist to pronounce on their Mesozoic character. In our district the whole series of Bunter rocks, representing a thickness of something like 2,000 feet, has failed to yield us a single fossil. The time taken to deposit this mass of

* "Geology of England and Wales."

† "Historical Geology."

rock is unfortunately not measurable, but must represent a very considerable lapse of time geologically speaking. Elsewhere in England and on the Continent the traces left are so few that no clear idea can be formed from them of the changes which were going on in the fauna and flora of Europe during the long period indicated, and it is not till we come to the Muschelkalk, a formation indicating entirely different conditions from those under which the Bunter sandstones and conglomerates were laid down, that we find any large assemblage of organic remains, from which it can be safely asserted that we have entered on the mesozoic stage of life.

In our own country we are still worse off, having no fossiliferous representative of the Muschelkalk. We have, however, in this district near the base of the Keuper, just above the conglomerate, a few fragments of Equisetæ, and, a little higher, numerous footprints of the Cheirotherium (an animal of which much less is positively known than is generally supposed), and of the Rhynchosaurus, as well as numerous casts of what may or may not have been plants.

In other parts of England in corresponding beds, and in others a little higher in the series, several bones of fishes and reptiles have been found, as well as the crustacean, *Estheria minuta.* So far, however, in this district no animal remains beyond the footprints have been found, and I would impress strongly on the members the great inducement there is to be constantly on the watch for them, for if the footprints and occasional casts of plants have been preserved, there is no reason why the occasional cast of a bone or two should not also reward careful and continued search in the Keuper sandstones and waterstones. Of the Bunter beds I am not hopeful—they seem persistently azoic.

During the deposition of the whole thickness of the Bunter the conditions seem to have undergone very little variation, and to have been unfavourable to the existence of animal or vegetable life. Under these circumstances we could hardly expect to meet in the beds above the Bunter with the descendants of animals or plants existing in the same area in Carboniferous or even Permian times, but with immigrants from other areas and of a different type.

What the conditions were under which the Bunter sandstones were laid down is a very fit subject for investigation by this Society, having regard to the opportunities presented by the fine development of this division in our neighbourhood. The enquiry is beset with great difficulties, but what enquiry worth making is not? The absence of organic remains in itself deprives us at once of one line of investigation pursued with success in other formations, and we are met at the outset with the necessity of accounting for it. The old idea that the colouring matter of red rocks was the cause of the non-preservation of organic remains is, I think, now generally discarded, for other sandstones quite as red are found to be full of fossils, and their absence, I think, must be accounted for by the conditions under which the beds were laid down.

Through a great thickness of the middle division of the Bunter we have numerous perfectly rounded pebbles of older and harder rocks irregularly scattered through the sandstone, and in other places lying in beds of consolidated gravel—and one of the first steps must be the examination of these pebbles and the determination of the character of rock they represent. This has been already to some extent carried out, and it is a matter in which all can assist, but when a more or less

complete list is formed, the finding the original source from whence they were derived will be a very difficult task. We may trace the erratics with some degree of precision in the case of our boulder-clay, but remembering the enormous amount of denudation that has taken place since Triassic times, we must acknowledge that the chances are against traces of the parent-rocks now existing in the position in which they were when the fragments now found as rolled pebbles were first detached.

Let me for a moment remind you of what the Bunter formation consists. We have here the soft variegated sandstones of the lower division, having occasionally a bed of conglomerate at its base, passing without any strong line of demarcation to the harder and coarser pebble beds. A very excellent section of this may be seen at Burton Point, at the top of the lower Bunter. There we find a few detached patches of coarse conglomerate alternating with beds of the usual soft sandstone, the latter gradually disappearing, and the rock becomes a continuous conglomerate. As we pass upwards the pebbles, which are all well rounded, become fewer in proportion to the sand, which is of a somewhat sharper character than that of the lower beds, and the sandstone is harder, the conglomeratic character gradually disappears, the pebbles are merely scattered irregularly through the sandstone, and whilst the sandstone itself continues the same in character the pebbles become less and less numerous as we reach the higher beds, until at the northern end of the section they are quite rare. I have described this section as I saw it a couple of months ago, and you will find a description of it, together with a sketch, in Mr. Hull's memoir, "Permian and Triassic rocks of the Midland Counties."

The pebble beds pass upwards into the upper mottled sandstone, almost identical in character with the lowest member of the formation, but in certain places harder and more compact.

I trust you will excuse me for reminding you of what is already very well known to you, but it may serve to render what I have to say more intelligible.

From Lancashire and Cheshire the formation extends across the Midland Counties, in a south-east direction into Warwickshire and Worcestershire, bending north-east again through Leicestershire and Nottinghamshire. This constitutes the main mass of the Bunter with which we are connected, and leaving out of the question for the present the outlying masses in the north and south-west of England. Whatever may have been the case with these latter, it is clear that the beds in the area described are one continuous deposit.

The pebble beds form the most persistent member of the formation. No pebbles are found in either the lower or upper mottled sandstone. They are numerous in the lower part of the pebble beds, more scarce in the upper. The pebbles increase in size as we go southwards, as well as in quantity, but the thickness of the beds is greatest in Lancashire and Cheshire, and as far as has been worked out the pebbles represent rocks now existing in the north.

Sedimentary rocks may be generally classed under four heads, viz.:—Sea deposits, estuarine deposits, deposits in the beds of rivers, and lacustrine deposits.

The theory of the marine origin of our Bunter sandstone presents so many difficulties that it has been generally discarded, so many things point to continental conditions having prevailed in Triassic times in this part of the world. The subsidence that appears to have gone

on during Carboniferous times ceased, and gave place to an upward movement. Ramsay suggested, though I am not sure that he was the originator of the idea, that both the old and new red sandstone formations were deposited in inland seas in process of drying up. This theory well accounts for the deposits of the saliferous marls which form so large a portion of the Triassic rocks, but it does not seem so satisfactory an explanation of the underlying sandstones.

An estuarine origin seems also out of the question, as all estuarine deposits with which we are acquainted shew alternations of sea and fresh water conditions, and are also generally prolific in organic remains. If there be one character more persistent than another through the whole series, it is the occurrence of a false bedding and evidence of strong and varying currents; in fact, through great thicknesses of rock there are few traces of still water, and this lends considerable support to the theory of their riverine origin held by Mr. Bonney. The action of flowing water would help to account for the scattered position of the pebbles, for you will remember that although there are beds of conglomerate and gravel, such as are formed in shore deposits, there are great thicknesses of rock through which the pebbles are scattered at irregular intervals.

Mr. Bonney, in a paper in the Geological Magazine for February last, on "The Rounding of Alpine Pebbles," arrives at the conclusion that to produce the condition in which we find the pebbles of the Bunter, they must have been rolled down by streams from mountains higher than the Alps, or along rivers for a distance of over 200 miles. We have no reason for supposing that mountains of that height, and composed of such rocks as we meet with in the pebble beds existed

at that time near the Triassic area, but if we allow for the fragments having travelled over 200 miles, it is more easy to account for their presence. The direction from whence they came is then the question. Mr. Hull and most writers consider that in this district they came from the north, and he suggests that the great increase in size and quantity to the south-eastward was caused by a further influx from old red sandstone rocks, formerly existing on the site of the German Ocean. Perhaps some light might be thrown on the direction of the flow if a great number of observations were made on the dip of the false-bedded rock; that is to say, not the actual dip as at present, but what it would be when the real bedding plane was in a horizontal position, as we may suppose it to have been at the time of deposition. It might be worth the while of some member to take this in hand, but it would involve a great deal of hard work before any trustworthy result would be arrived at.

There is, I think, no doubt that a constant process of re-assortment was going on during the deposition of the whole formation; but if that re-assortment were aqueous, we may arrive at some results worth having by a thorough examination of the direction of the currents such as I have suggested.

On the other hand there is the possibility that much of the re-assortment may have been aërial; that after a certain amount of sand had been deposited, it was laid dry and subjected to the action of the wind. Mr. J. A. Phillips, in a paper on the History of Grits and Sandstones read before the Geological Society in 1881,* suggested the Eolian character of the sand from several beds of the upper and lower mottled divisions. Mr. G. H. Morton read a paper on the microscopic

* Q.J.G.S., vol. 27, page 12.

character of the sandstones of this district before our Society in December, 1885, and his description of these sands confirms Mr. Phillips' suggestion. It is now well known that grains of sand are much more rounded by wind action than by the action of water. There is still room for further work in this direction.

In May last Lieut. F. E. Younghusband gave an account of his recent journey across Central Asia to the Geographical Society.

He mentions a range of hills of sand forty miles long and rising to a height of 900 feet, without a vestige of vegetation upon it, and he attributes its formation to the action of westerly winds.

Speaking of the Altai Mountains, he says: "These "mountains are perfectly barren, the upper portion "being composed of bare rock and the lower of long "gravel slopes formed of the débris of the rocks above. "In such a dry climate, exposed to the icy winds of "winter and the fierce rays of the summer sun, and "unprotected by one atom of soil, the rocks here, as also "in every other part of the Gobi, crumble away to a "remarkable extent, and there being no rainfall suffi-"cient to wash away the débris, the lower features of the "range get gradually covered up with a mass of débris "falling from the upper portion, and in course of time "a uniform slope is often created thirty or forty miles "in length, and it is only for a few hundred feet from "the top that the original jagged outline is seen."

We have here an extreme instance of Eolian denudation and deposition—of moving air, aided by rapid and extreme alternation of temperature doing the work we usually attribute to the action of water. I would suggest that some such action may have assisted in laying down the Bunter Sands as we now find them during intervals when the Triassic river or rivers ran dry.

Before leaving the subject of the Bunter, I would just refer to the rather puzzling bed of breccia exposed at the mouth of the Dee. Throughout the pebble beds the included pebbles are almost invariably of rocks of a very hard character and which are not found in sitû in the neighbourhood, and are all more or less rounded; but a bed which is exposed on the S.W. side of Middle Eye and at Hilbre Island is full of angular fragments of various sandstones, limestones, and other rocks—some apparently from Carboniferous beds; there are also very numerous fragments of rock quite similar to the red beds of sandstone still found in sitû immediately below the breccia. Such a bed as this in this position is, I think, worthy of some attention, as indicating a sudden temporary change of conditions. It appears to me to be not at the base but well up in the pebble beds. We have always supposed this to be the case, and the rocks are so coloured in the Survey maps; but I am aware that it has been suggested that they are Keuper, and are mentioned as such in the last number of our Proceedings. I certainly, when there a few weeks ago, detected pebbles in the underlying beds which would hardly have been the case had the breccia been the basement bed of the Keuper.

The tracing of the junction of the Bunter and the Keuper must always have a great interest for local geologists. The actual junction is not so generally exposed as might have been expected, owing to the fact that the stone has been worked in the quarries down to the top of the conglomerate at the base of the Keuper, and the workings have not been carried through it.

The lower Keuper in this district, as you know, consists generally of a bed of conglomerate at the base passing upwards into building stone with a few pebbles, and at first sight it might be supposed that the Upper

Mottled Sandstone bore the same relation to it as the Lower Mottled Sandstone does to the pebble beds, the more so, as the Keuper building stone often so nearly resembles that of the Pebble beds that it is impossible to distinguish them. But this is not the case, for there is here a distinct break, and the Keuper conglomerate is frequently seen to rest on an uneven and evidently denuded surface of the Upper Mottled Sandstone.

The most convenient place just at present for seeing the junction of the two divisions is at Flaybrick, where it can be seen in the quarries on both sides Tollemache Road. An irregular bed of conglomerate rests on the Upper Bunter with some laminated sandstone associated with it. Above this, about 6 or 8 feet of poor building stone, overlain by a very irregularly bedded series of coarse conglomerate and sandstones, the lower part of which contains numerous fragments of beds of marly shale very irregularly disposed; indeed, perhaps the most characteristic feature of these basement beds is the quantity of fragments, rounded and otherwise, of clay and shale.

The irregular arrangement, or rather heaping together of the different beds, and their varying character, would suggest more violent and varied action, than that which prevailed in Upper Bunter times.

The lower Keuper beds in our neighbourhood are very much jointed and broken, and many of the joints are horizontally, and others obliquely, striated, indicating movement in those directions. I have, from time to time, brought instances before the notice of the Society. So far I have not been able to trace any of these striated joints down into the Lower Bunter, in which the system of jointing seems to differ greatly from that of the Keuper; it therefore follows that the probability is that there was a horizontal movement of masses of the

Keuper Sandstone over the Bunter below, and it might be expected to have left some trace. At one time I thought that this was to be seen at Wallasey, where a bed of shale is seen to have been broken up and turned over, the sharp edges of the fracture being plainly seen, and the fragments mixed up with a coarse conglomerate; although, at this point, the base of the Keuper is not seen, the broken bed occupies the same position with regard to it as does that just described at Flaybrick (with which the section corresponds), where no indication of horizontal movement has been found. Again, at Helsby, where the lower beds of the Keuper are finely exposed, both the natural and artificial sections, there is a very irregular bed with lumps of broken up shale, in what appears to be the same relative position.*

I would recommend the study of this interesting bed to the attention of members, and a comparison with the beds at the base of the pebble beds in localities where they are more coarsely conglomeratic. The history of its formation is not at all clearly shewn, and I can even imagine an enthusiastic glacialist seeing in it a proof of ice action in Keuper times.

Sir Chas. Lyell it was I believe, who first suggested a similarity of some of the Triassic beds to those now being formed along the northern shores of the Mediterranean, where the violent and temporary torrents descend from the Maritime Alps to the sea; and should any of our members visit the Riviera, I wish they would carefully examine any sections they may find there, and compare them with sections of the Trias here.

Above these conglomerates are more compact beds of building stone, with occasional layers of lumps of clay and shale, and at intervals, beds of the same. In some

* "Geol. of Neighbourhood of Chester." A. Strahan, M.A., F.G.S., &c. page 7.

of the finer beds of clay animals have left their footprints, and in a few cases stems of plants their impressions, and it is on the under surface of the overlying sandstone that we find casts of the same. Here, for the first time in this neighbourhood, after leaving the Carboniferous rocks, do we find any organic remains. I would suggest an active search here, and also among the shales overlying the building stone for further fossils, as well as in the overlying waterstones, but opportunities for exploration are not so frequent here as in the beds below. Where the beds occur in Liverpool, the ground is mostly built over, but the shales may be seen in the old quarries now converted into St. James's Cemetery. The waterstones may be seen on the rising ground in the centre of Wirral, and a good section of Red Marl at Woodchurch. The Red Marl occurs on the top of the hill at Oxton, but is only exposed in occasional openings, so that unfortunately, the beds above the Keuper building stone are not well situated for observation. This is the more to be regretted as it is on this horizon that in other localities vertebrate remains have been found.

I have purposely omitted in the foregoing sketch any attempt to explain the various phenomena by theories of my own, but have endeavoured to place before you sundry questions that may usefully occupy the attention of members of the Society. I have not touched upon the Carboniferous rocks with their rich stores of organic remains, which are within easy reach of us, nor on many other questions that will readily occur to all of you; but I trust I have said enough to shew the falsity of the saying that there is no geology about Liverpool, but that on the contrary there is at our very doors ample material for all that energy and activity in original research, which I trust will continue to characterise this Society.

NOTES ON THE LOCAL HISTORICAL CHANGES IN THE SURFACE OF THE LAND IN AND ABOUT LIVERPOOL.

By Sir J. A. Picton, F.S.A.

The surface of the earth on which we dwell has by no means the stability which we ordinarily assign to it. Not to speak of the wonderful vicissitudes in the earth's crust which geology unfolds to our view, there have been in all ages forces at work, which still continue, realising the prophecy, "Every valley shall be exalted, and every mountain and hill made low. The crooked shall be made straight, and the rough places plain."

The greater part of these changes are due to natural causes, over which man has no control, but a considerable portion have been effected by human agency.

The cultivation of the land, the cutting down of the forests, the draining of the marshes, the embankments of the rivers, the improvement of the watercourses, the construction of canals and railroads, have imparted to the country an entirely different aspect from its original natural character. Wherever a town exists, not only has the levelling process been going forward, but the surface is being gradually raised. The Forum of the city of Rome was originally more than twenty feet below its present level, and modern London has risen in a still greater proportion above its Roman predecessor.

Perhaps the most remarkable instance of this tendency is to be found in the explorations of M. Schliemann on the site of ancient Troy, where there were palpable evidences of the remains of at least three cities built vertically one over the other.

The city of Liverpool is not possessed of sufficient antiquity to exhibit alterations in its site on a grand scale, but since its foundation there have been many and great changes in its superficial contour which are well worthy of notice.

This subject was ably treated by Mr. G. H. Morton, in his Presidential Address of last year, and much light was thrown on local phenomena which are not obvious to a casual observer. The object of the present paper is to add a few further observations bearing on the same subject.

The tendency of all operations on the surface of the land, within the historical period, has been to cut down the eminences and raise the hollows, and thus to bring the gradients more to a regular slope. The excavations for stone and brick clay used in building have had a very marked influence on the changes of level during the last two centuries. The laying out of new streets and preparing the ground for building has had the effect of obliterating every prominent feature of moderate size, and of smoothing down the ruggedness of those of greater magnitude.

At the close of the glacial period, and during many succeeding ages, the landscape on the east side of the Mersey presented a very picturesque aspect, resembling in many respects the eastern slope of Bidston Hill, on the opposite side of the river. The rocky descent from the high lands at Everton, Low Hill, and Edge Hill, was here and there broken up into crags and precipices, with deposits of clay in the hollows. This declivity was interrupted by two ancient sea margins, referred to by Mr. Robert Chambers in his work on the subject. One such occurs near the summit of William Brown Street, just under the Rotunda Lecture Room and the Walker

Art Gallery, the direction of the strike being along Lime Street. Here there is a marginal deposit of pure white sand, without a boulder or a pebble, and so dry that the benches in the Lecture Room are cut out of it. The upper sea margin constitutes the flat at the foot of the eminence of Low Hill running southward to Parliament Street, which was the site of the ancient Moss Lake. Under the lower terrace a large boulder was found ground to a flat surface and strongly marked with glacial striations.

On the summit of Low Hill there was a pre-historic tumulus, called in Anglo-Saxon, "*Hlaw*," from which the hill takes its name.

. On the site of University College a rocky eminence reared itself, called the "*Brunelagh*" or Brown-low, which served for many generations as a quarry for building stone. It is a curious instance of the manner in which the primitive features of a locality impress themselves for ages, and are almost ineffaceable. On examining the map of Liverpool, it will be seen that the street called Mount Pleasant running eastward up the slope, when it arrives at the western margin of the ancient terrace opposite the end of Hope Street is deflected to the north. Smithdown Road coming from the east, when it arrives at the eastern margin of the same terrace, is similarly deflected. The curved line thus formed marked the edge of the ancient Moss Lake which extended to the foot of the "*Brunelagh*," or Brown-low, just mentioned, leaving a narrow pass between the rock and the moss not unlike, on a small scale, the Pass of Penmaenmawr. Every feature of this has been long obliterated. The rocky eminence has been quarried away, leaving a deep chasm which in its turn has been filled up, and covered with public buildings. The Moss Lake has been drained

c

and laid out in streets and squares, leaving as its only relic the peaty soil below the foundations; but the contour and plan of the streets and the name of the central feature remain, indelible monuments and connecting links of a far-away primitive age.

Proceeding southward, the sandstone rock cropped out at numerous points: in Hope Street, near the site of the Philarmonic Hall, where, on a small eminence, an Observatory was commenced in the year 1766, but never completed, owing to lack of funds; again in Hardman Street the rock rose above the level.

A little further south, the site of St. James's Cemetery formed a rocky hill, commanding an extensive panorama. This eminence was quarried away during many ages.

The upper terrace presented several precipitous features about Edge Hill. The streets leading downwards—Irvine Street, Paddington, and Grinfield Street—show distinctive marks of having been cut through the rock.

The Moss Lake formed the principal, but not the only, source of the brook, or rivulet, which fed the pool from which the city takes its name. Its direction is correctly described by Mr. Morton. In its course along the upper terrace it was a smooth, placid stream, but in turning westward, between Stafford Street and Byrom Street, the gradient became steep, and the fall rapid. Hence it acquired the name of *Stirpull.*

In the Testa de Neville, written about the middle of the 13th century, reference is made to this brook, as defining certain boundaries. The line is set out as "from the Park (Toxteth) to Bromegge (Broom-edge), and following Bromegge to the Brown-low and thence crossing to the ancient turbaries between the two meres up to Lambisthorn, descending to the Waterfall of

Stirpulhead, and following Stirpull in its descent to the Mersee."

Following the edge of the eminence from Edge Hill northwards, the tendency everywhere has been to cut down and level the irregularities of surface, and to hide them by buildings. Within the city these operations were still more pronounced. The site of the Castle, now occupied by St. George's Church, stood formerly much higher than at present. In the year 1700, the ground was ordered to be levelled for a market place. When the Church was built (about 1725), the surface was nearly as high as the present terrace. A flight of stone stairs, called Kenyon's Steps, led down to Preeson's Row, and another flight, called Temple Bar descended to Pool Lane (now South Castle Street). In 1756, the surface was lowered and the terrace and vaults built.

At the north end of St. George's Hall the ground was originally much higher than at present, as was evident by the flights of steps to the houses, long since removed. The surface has been cut down more than once.

At the north, there has not been very much alteration. Nash Grove and the neighbourhood was formerly a natural deep dell, or ravine. Bevington Hill was a rocky eminence, crowned with several villas and gardens.

In ancient times, and long within the historic period, the aspect of the landscape hereabouts must have been seriously affected and modified by the numerous streams or watercourses which arose in the high lands in the east, and debouched into the Mersey. They were all of them small, being limited to the comparatively narrow verge below the hills.

Beginning at the north end, we have first the Rimrose, or Primrose, Brook, which divides Linacre from Lither-

land. This was anciently a considerable stream formed by the junction of two rivulets, one running from north to south, being the drainage of Litherland Marsh, the other from east to west, taking its rise in the high land about Orrell. From a pool, or *linn*, in this brook, the township of *Lin-acre* probably derives its name.

Next comes the brook rising from the Bootle springs, which were so copious as to turn a water mill within a hundred yards of their source, and which, until recently, contributed a large proportion of the supply of Liverpool.

Succeeding this was the Bank Hall Brook, now entirely obliterated. This was formed by the junction of two branches, rising in the higher grounds of Kirkdale and uniting in a hollow between the two eminences on which now stand the Kirkdale Gaol and the Industrial School. It then passed into a deep dingle, part of which, I think, still remains on the south side of the road to the gaol, formerly occupied by tanners' and skinners' yards. It then crossed the site of Stanley Road and formed two pools, between which stood the ancient Bank Hall. From thence, it reached the river about the centre of Huskisson Dock.

Next came Beacon Gutter, which formed the division between Liverpool and Kirkdale, and took its name apparently from a beacon or sea-mark erected at its mouth. It brought down the drainage of the western slope of Everton.

Then followed the *Stirpool*, the stream which fed the *Liver-pool*, and which has been set forth in Mr. Morton's address.

Another rather considerable stream, to which I can find no name attached, took its rise at the north end of Lodge Lane, near Smithdown Road. Crossing Park Road, it formed a mill dam, to which there was also a

windmill attached. Thence it reached the river, a little to the south of Parliament Street, near the site of Coburg Dock, where there was another dam and another windmill.

We proceed next to Knot's Hole Dingle, an inlet on the west side of the bluff rocky promontory. This stream arose at the top of the descent in Park Road, leading down to the ancient chapel.

On the east side of the bluff there was another stream, which rose near the south end of Lodge Lane and debouched near St. Michael's Hamlet in what was called "Dickinson's Dingle."

Lastly came Otterspool, which was formed by two branches: one rising in Wavertree, near the site of the railway bridge. The other passes Green Bank, where it forms a considerable pool. This rivulet, called the Jordan, runs through Sefton Park, and supplies the water to the lakes. Otterspool was formerly an inlet of some importance, forming a small harbour, into which vessels of 100 to 200 tons could enter.

It would be useless to proceed further south, but there are other small streams debouching in various places.

Before the vast accumulation of bricks and mortar which has obliterated the primitive features of the locality, Liverpool must have been a pleasant place of abode. Its wide open heath, its undulating surface, its rocky eminences commanding splendid views over the sea and river, and its numerous water-courses, imparted a variety and picturesqueness to the scene which was striking and remarkable. It is well to place on record a few notices of the salient points before they are entirely forgotten.

Before concluding, I wish to add a few words on the post-glacial geology of the two river basins of the Mersey and Dee. The subject has been ably treated by Mr. Mellard Reade and Mr. Morton; but there are one or two aspects of the problem to which I wish to call attention.

The estuary of the river Dee, as is well known, has for many ages been undergoing a process of shallowing and silting up, until it has almost become unnavigable except for very small craft. There are only two modes by which this result could take place—either by the accumulation of débris brought down from the upper course of the river, or by the sand and silt brought from the sea by the rush of the tide.

The influence of the first of these must always have been trifling. The river runs over a bed of slaty rock, and preserves its limpid purity down to a few miles above the tidal junction. Whatever the cause may have been, its visible influence is confined to the estuary. One phenomenon is very apparent on both sides for some distance above and below Chester, namely, the old coast line, which gives unmistakable indications that at a former period the water stood much higher in relation to the land than it now does. Along the margin there first occurs a breadth of flat land very little raised above the tidal level, succeeded by a deep scaur of friable soil, evidently worn down by the action of water. We know that the level of the sea has not changed, and are driven, therefore, to the conclusion that it is the land which has altered its level; that there has been a slow gradual elevation during a long period of time, and probably still going forward.

In addition to the appearance of the old coast line, there is the evidence of the Roodeye, now the race-

course but formerly a haven for ships, with a considerable depth of water. The Romans had here an emporium or wharf, the remains of the sea wall of which are standing to this day. The material of the present surface certainly cannot have been brought down the river, and it displays no evidence of sand and silt, which would have been the case had it been brought in with the tide. I cannot, therefore resist the conclusion that there has been a gradual rise of level of the Dee Valley in its lower portion, during many ages. This is confirmed by the appearance of the coast about the Point of Aire, where the sandy waste is evidently gaining on the sea.

In Mr. Morton's address it is stated that "the Dee has a bordering forest bed, several miles in length, along its north-eastern margin and marshes along the opposite coast." I am prepared to receive with implicit credence whatever is stated by so high an authority from actual observation, but that is not here stated.

Another statement is quoted from Mr. Wm. Shone, F.G.S., that "a tract of land, about a mile in width and about six miles in length, between Hilbree Island and Heswall, and formed of boulder clay, has been swept away in comparatively recent times." This would necessarily imply that the coast between Gayton and Neston, including the ancient port of Parkgate, had in recent times extended a mile out into the estuary. For this statement no authority whatever is given, and the evidences are all in the opposite direction. Down to the first quarter of the present century the Irish packets sailed from Parkgate; and the cheesemen, which carried the produce of Cheshire to the London market, lay in deep water in Dawpool at all times of the tide.

Within the memory of persons now living, a small steamer plied across the estuary between Parkgate and Bagillt at all times of the tide. She was taken off owing to the shallowing of the channel. The sailing ferry boats which succeeded were gradually restricted to making the passage a little before and after high water, having at neap tides to make a considerable detour. At length it became impracticable to ensure the crossing at any time, and the ferry was given up, and the old Boat House Inn, which had stood for hundreds of years, was taken down.

When we look at the estuary of the Mersey we find a very different state of things. Here the channel has been gradually deepening. There is no old coast line such as exists on the Dee. On the contrary, there has been going on for ages a constant erosion of the coast. All the phenomena point to the conclusion that the water has, from an early period, been gaining on the land. It is well authenticated that large tracts between Dingle Point and Hale on the Lancashire side, and about Stanlow on the Cheshire coast, have been swept away; and the fretting action is still going forward.

The Cheshire coast line, from Birkenhead to the Rock Lighthouse, presents the appearance of a clay bluff gradually wasted away by the action of the tides. Comparing the present charts of the river with those of a century ago, there is a considerable increase in the depth of water both in the channels and over the bar, and there is reason to believe that this action is still going forward.

Again, the forest beds on both sides of the river indicate that there has been a considerable subsidence in (geologically) recent times. The peat beds about Southport and the neighbourhood dip under the sea

and crop out near the surface about two miles inland. When the peat was formed the surface must have been above the sea level.

The forest bed under the Albert Dock, described by Mr. Archer, and quoted in Mr. Morton's address, extended also to the site of the Custom House, formerly the Old Dock, where similar vegetation was found. Mr. Morton has well described the course of action by which these changes were effected, and, I think, has satisfactorily solved the difficulties which present themselves. That portion of his paper is specially worthy of study.

There is only one other point to which I will allude,—which is the singularity of the diverse action going forward in two estuaries so near to each other: a gradual subsidence in the one case, and an equally gradual elevation in the other. We cannot shut our eyes to the evidence of the facts and phenomena around us.

The neutral axis appears to run along the middle of the Wirral peninsula, reaching the sea between Hoylake and Leasowe. At Leasowe the sea has gained considerably on the land. At Hoylake, if the actual land has not gained from the sea, at least the old Hoyle Lake and its channels have been so far silted up as to be dry at low water.

The changes above alluded to are so gradual as almost to escape notice. It is only by comparison of observations made at distant periods that a correct idea can be formed of their nature and influence, and unfortunately these are wanting. I would instance the northern coast of the Baltic Sea, which has been proved by comparison of data at different periods to be gradually rising at the rate of about a foot in a century.

The globe which we inhabit is not a mere inert mass. There are forces at work of tremendous power, elevating, depressing, modifying, changing the wilderness into a fruitful field, or, on the other hand, spreading desolation and ruin over wide tracts. In our own happy land these operations are gentle and slow, but they exist and cannot be ignored. The greater or less depth of water in a river channel may change the course of commerce and affect the welfare of millions. It behoves us, therefore, to keep a watchful eye on these processes of Nature going forward, to bring whatever intelligence we possess to counteract any injurious tendencies, and to take advantage of, and aid by science and skill, whatever makes for the benefit of our race and age.

THE PERMIAN CONGLOMERATE, AND OTHER PALÆOZOIC ROCKS TO THE NORTH OF MORECAMBE BAY.

By J. J. Fitzpatrick.

The promontory, or bluff, called Humphrey Head, which juts nearly due south into Morecambe Bay, is one of the most striking features of the scenery near Grange-over-Sands. This Head is formed of Carboniferous Limestone, with encrinites, *Productus*, *Spirifera*, and other characteristic fossils.

At low tide the whole of this peninsula can be examined. It is nearly a mile in length, and averages 300 yards in width; in its highest part it is 170 feet high. This bold headland forms a prominent object which can be seen from a considerable distance.

Nearly 700 feet due west of Humphrey Head there is an isolated hillock of low cliffs of an oval shape, and

surrounded by the sand and shingle of the sea-shore. It is to this small patch of rock, called Rougholme, that I desire to call attention. This outlier is remarkable as being the only exposure of the Permian Conglomerate, or "Brockram," in this locality. The name "Brockram" (meaning broken rock) is applied locally in the Vale of Eden to deposits closely resembling the brecciated conglomerate of which this rock is composed. The length of the outlier is about 900 feet, by 500 in width.

Owing to the constant action of the tides and of subaerial denudation it is slowly but surely getting smaller in size, and its fragments are being scattered once more upon the sea-beach of modern times. An effort is now being made to save it from the inroads of the sea by the construction of a primitive breakwater, which is being built from the rocks of the conglomerate itself. This is probably done because the outlier is covered with a soil which is found suitable for cultivation, and its value is therefore much enhanced. I have roughly measured the strata from the beach in various places, and found that portion of the rocks facing Humphrey Head, or due east, to be 7 feet in height, facing south-east 8 feet, due south 12 feet, west 15 feet, and north from 25 to 30 feet.

In the centre of the outlier the height is nearly 50 feet. The dip of the strata is 9° nearly due south. On all parts of the cliffs the stratification is admirably displayed. The total thickness has not been ascertained, as no boring has been made near the conglomerate, and in no instance has it been reliably recorded that fossils have been found in the fragments, but this is accounted for by the chemical change, through the limestone becoming dolomitised. I have already indicated the relative position of the "Brockram" with regard to the

Carboniferous Limestone promontory of Humphrey Head. It is well to state that the flat strip of land to the north and north-west of the conglomerate is covered with boulder-clay, locally called "Pinel," and the solid geology of a great part of this district is much hidden by thick deposits of this "Pinel."

By means of bore-holes sunk in search of iron ore it has been ascertained that the St. Bees Sandstone (Upper Permian) is under the covering of boulder-clay, at a distance of half-a-mile to the north of the conglomerate. A little further to the north the Carboniferous Limestone rises into hills of considerable elevation, the highest being Hampsfell, which is nearly 800 feet. As to the composition of the conglomerate, it consists almost wholly of sub angular and rounded fragments of Carboniferous Limestone, which have become entirely dolomitised, and therefore the more correct expression would be to call it a dolomitic conglomerate or breccia. Besides the limestone there are small rounded and sub angular pebbles of quartz, but these do not enter very much into the composition of the rock. The fragments of limestone vary in size from the smallest particle to two or three pounds in weight. These are cemented together in a sandy-calcareous matrix. Many of the pieces of limestone have cavities caused by the action of water dissolving the carbonate of lime, which appears to be the chief cementing agent in the formation of the conglomerate. Calcite crystals are to be seen in different parts, thus indicating a redeposit of the lime dissolved from the weathered fragments having cavities, and also showing how the lime was produced which enters into the composition of the matrix.

Several layers of a fine reddish sandstone, each layer being from one to about three inches in thickness,

are interbedded with the conglomerate. This soft sandstone is of special interest, as it probably indicates oscillations of level. As this sandstone is entirely free from limestone fragments, it contrasts in a remarkable degree with the coarse composition of the actual conglomerate. It is entirely a siliceous deposit intercalated with the rough calcareous strata of the conglomerate. In a note appended to the six-inch map of the Geological Survey, it is stated that sandstone pebbles are found in the conglomerate; but after the most diligent search on several occasions I was unable to find a single specimen. Mr. Thomas Hart, F.G.S., of Yewbarrow, who has lived in the district for many years, and who kindly accompanied me on the occasion of one of my visits to the conglomerate, has often sought for them, but has also been unable to find any.

Many of the small limestone pebbles are so much weathered, and of such a reddish colour, that unless tested by acid they may readily be mistaken for sandstone. The following are the chemical constituents of a characteristic fragment of this magnesian limestone:—

Carbonate of lime	54·70
,, magnesia	45·30
	100·00

The cementing material consists of:—

Carbonate of lime	37·80
,, magnesia	28·40
Silica	10·00
Peroxide of Iron	3·10
Alumina	16·20
Alkalies	2·50
Water	2·00
Phosphoric acid	traces
Manganese	traces
	100·00

A descriptive note appended to the 6 inch Geological Survey Map referring to this remarkable formation says:—"'Rougholme'—A very coarse conglomerate "made up chiefly of semi-rounded fragments of Carbon-"iferous Limestone and some reddish sandstone "pebbles, mostly small, cemented compactly in a red "sand. There are also a few small lenticular beds of "soft red sandstone. The fragments of limestone vary "from about the size of a man's fist downwards to small "grains. The beds are like the Magnesian Conglomerate "of Bristol and South Wales; Brockram of the Vale of "Eden."

I have so far endeavoured to give a sketch of the physical features and chemical composition of this deposit, and I will now refer briefly to a theory to account for its origin. In the year 1855, Professor Ramsay ascribed the formation of similar deposits in Shropshire and Worcestershire to the action of glaciers and icebergs in the Permian Epoch, the substance of his theory being that such breccias and conglomerates were formed by the moraine matter of glaciers being drifted on icebergs and deposited in the Permian Seas. Mr. R. Russell, F.G.S., H.M. Geological Survey, in a Paper read at the meeting of the British Association at Belfast, in the year 1874, agrees with this theory, and referring to similar deposits near Whitehaven, says:—"Notwithstanding the angular "and subangular character of the pebbles there is much "regularity in the stratification, and the distinct bedding "shows that the materials must have been deposited in "deep and still water, so that we cannot ascribe their "formation to the transporting power of running water or "tidal waves and currents, for the continued action of "these causes would have destroyed the distinctive "characteristics, viz:—angular shape of the fragments,

" and the pebbles would have been rounded. Ice solves "the problem. Periodical ice-floes cause regular bed-"ding." (The conglomerate referred to in Mr. Russell's paper contains a greater variety of rock fragments than the deposit near Humphrey Head). Whether this ice action theory is the correct one, it is difficult to say. It has not been accepted by all eminent geologists, and it is certainly a problem difficult of solution. Geological theories have to be advanced with great caution. No doubt periodical summer floods caused by the melting of snow on the mountains of Permian times had a great deal to do with the deposition of these and similar rocks.

Having now completed my sketch of this highly interesting conglomerate, which I hope at a future time to compare with the Permian Breccias of Shropshire and of the Vale of Eden, I will add a few words about the older Palæozoic rocks of this district, which is known as North Lonsdale.

The Carboniferous Limestone of Humphrey Head is noted for a saline or brackish spring, which may be seen on the western side of the Head. This spring is mentioned in Baines' "History of Lancashire," and Dr. Barber, in the new edition of that work, gives a full account of this mineral water, which is known as the "Holy Well of Cartmel." The spring rises at the base of the cliff, and is supposed to be possessed of curative properties in cases of gout and rheumatism. A little to the north of the spring, about half-a-mile, it has been ascertained by boring through the heavy covering of boulder-drift that the St. Bees Sandstone (Upper Permian) is to be found. This St. Bees Sandstone borders the coast in a thin line from Humphrey Head to the estuary of the Duddon, and it is remarkable as being one of the best building stones that can be used.

Furness Abbey, that gem of Norman architecture, founded in 1129 by Stephen, Earl of Boulogne, was built of this excellent fine-grained building stone, which has endured the atmospheric action of more than seven centuries without suffering much from weathering and decay.

The Bannisdale Beds (Upper Silurian) upon which the ancient town of Cartmel is built, are to the north-west of the conglomerate at a distance of two miles. Cartmel is situated exactly at the junction of these rocks with the Carboniferous Limestone. The former are the equivalents of the Wenlock Shale and Lower Ludlow Rocks. At Lindale, two miles from Grange, these rocks are faulted against the Carboniferous Limestone. The direction of the fault is from south-east to north-west. The Upper Silurian Rocks occupy the chief part of the area of North Lonsdale, and are continuous as an elevated ridge from Lindale, where the dip is 25° to Lake Windermere.

This ridge gives evidence of much folding and contortion, and the dip varies from 15° to 65°. The following rocks are met with within a radius of five miles of Broughton-in-Furness:—

Permian.	
Carboniferous	Yoredale Rocks.
	Carboniferous Limestone.
Upper Silurian	Coniston Flags and Grits.
	Stockdale Shales.
Lower Silurian	Coniston Limestone Series.
	Volcanic ,,
	Skiddaw ,,

It is desirable to make the ascent of that charming and beautifully wooded hill of Carboniferous Limestone

called Hampsfell, which, with Yewbarrow, protects Grange from the cold north wind, and which rises in a series of graceful and picturesque terraces to a height of 727 feet above sea-level. During an ascent I examined a number of Silurian boulders and perched blocks exactly similar to those which I had the pleasure of visiting in company with Dr. C. Ricketts, F.G.S., at Norber Scar, near Settle, in the North-West of Yorkshire. Most of these boulders are near the summit of the hill, but several are also scattered over a field near Boar Bank, to the west of Hampsfell. These boulders indicate ice action in comparatively recent times. The view from the summit in clear weather embraces a splendid panorama, including, towards the south, the whole of Morecambe Bay, with its beautiful surrounding hills, the highest being Littledale Fell (1836 feet), which is capped with Millstone Grit. Due west is Walney Island, which is covered with such a thick deposit of boulder-clay that it is only surmised that the solid rock beneath is the St. Bees Sandstone. Looking to the north-west, the gloomy Cumberland hill called Black Combe is seen in the distance. This hill is formed of Skiddaw Slates (Lower Silurian), and is 1969 feet above sea-level. To the east the noble form of Ingleborough, 2,373 feet, with its cap of Millstone Grit, is a striking object on the horizon.

FURTHER NOTES ON THE STANLOW, INCE, AND FRODSHAM MARSHES.

By G. H. Morton, F.G.S.

In the Paper I read before this Society last session, I described sections of the Peat-bed, Estuarine Silt, Boulder-clay, and the Pebble-beds of the Bunter formation exposed along the southern shore of the Mersey, between Ellesmere Port and Holpool Gutter. This was before the excavations for the Manchester Ship Canal began—before a spade had been brought on the ground. I referred to the great engineering work about to commence, and the splendid section that would be soon exposed across the country. I also mentioned a series of trial holes and borings that had been made, and stated that they did not afford much information as to the Recent and Post-glacial beds along the coast.

I referred to three difficulties, which neither the natural sections nor the artificial borings explained. Firstly: the average depth of the Peat-bed beneath the superficial bed of Estuarine Silt. Secondly: the reputed existence of another bed of Peat beneath the lower bed of Estuarine Silt exposed on the shore; and Thirdly: the character of the bed of sand exposed by the Lighthouse at Ince. During the excursion of the Society with the Naturalists' Field Club in May last, so little progress had been made with the excavations and so little time could be devoted to them, that no additional information was obtained. The sections, however, exposed at Ince and other places along the shore were uncovered by the tide and seen by the members who attended the meeting.

Considerable progress has since been made with the excavations, and I find that the depth of the Peat-bed, beneath the surface, may be considered on the average, about 6 feet—that of course being the thickness of the overlying silt, which is less than I expected. The surface of the Peat, however, presents an undulating contour, varies in thickness, thins out against rising ground, and is often altogether denuded. The occurrence of a Lower Peat-bed has been proved over a considerable area inland, though not along the coast. It is interesting to find that the Lower Peat sometimes runs into the Upper Peat, when both continue as a single bed and join the present surface, where it has never been covered by recent deposits, but this is not seen in any coast section.

The Upper Drift Sand does not occur as supposed, for the sand described by Mr. Strahan is simply an arenaceous condition of the Estuarine Silt, beneath the Upper Peat-bed. The change from clay to sand and from sand to clay may be seen in the excavation on the east of Ince Lighthouse.

So far as the destruction of Stanlow Abbey, 600 years ago, affords a means of ascertaining the rate of deposition of the Estuarine Silt is concerned, it may have been on the average one foot in 100 years, but it is improbable that much was deposited during the last century, since the land has been partially protected from the sea. It would, however, be easy to find limited areas where the accumulation had been about 6 feet in 100 years. On the scores, outside the embankment, about an inch each year is indicated by the successive lines of dead grass which indicate the upward growth of the silt from year to year, but this rapid deposition is quite a local condition near the river. Assuming the silt above

FURTHER NOTES ON THE STANLOW, INCE, AND FRODSHAM MARSHES.

By G. H. Morton, F.G.S.

In the Paper I read before this Society last session. I described sections of the Peat-bed, Estuarine Silt Boulder-clay, and the Pebble-beds of the Bunter forma tion exposed along the southern shore of the Mersey between Ellesmere Port and Holpool Gutter. This was before the excavations for the Manchester Ship Can began—before a spade had been brought on the groun I referred to the great engineering work about commence, and the splendid section that would be s exposed across the country. I also mentioned a se of trial holes and borings that had been made, and sta that they did not afford much information as t Recent and Post-glacial beds along the coast.

I referred to three difficulties, which neith natural sections nor the artificial borings expl Firstly: the average depth of the Peat-bed benea superficial bed of Estuarine Silt. Secondly: the r existence of another bed of Peat beneath the low of Estuarine Silt exposed on the shore; and Thirdly character of the bed of sand exposed by the L house at Ince. During the excursion of the Societ the Naturalists' Field Club in May last, so litt had been made with the excavations a could be devoted to them, that no addit was obtained. The sections, howev and other places along the sh tide and seen by the mem

corrections
w to bring
ng the last
h is nearly
ards inland.
be 120 feet
ng outwards
nks, so that
ch narrower
radual slope.
l the level of
urface. The
e excavations
s a mile, the
in progress.
the requisite
15°, and this
both sides of
rom further

hes are not
livided into
of bosses
pwards at
f silt and
slopes of
sections
measures,
of coal
tions a
een it
of peat
as they

the Upper Peat-bed began to accumulate at the end of the 13th century, and that it has an average thickness of 6 feet, it may be supposed to average one foot in 100 years.

Nothing of Historical interest has been found during the progress of the excavations. One of the gangers informed me that a "Roman stone," as he called it, had been found of a rectangular form and beautifully polished, but he could give me no further information, or tell what had become of it. From what I heard I concluded that it might have been a worked slab from the ruins of the Abbey, for it was found near the surface and within a quarter of a mile off. I have not seen any indication of any road across the line of the canal below the present surface, but there is none along it now, and a road to the Abbey in the olden time would leave little trace of its course.

A search at Stanlow House about the old stone walls, in the stables and other outbuildings has not brought much to light. Little could have remained of the ruins of the Abbey when the present farm house was erected with bricks, and the stone has evidently been used in the construction of the outhouses and boundary walls. The house and other buildings were probably erected about 100 years ago. Four pillars form part of the wall of the low buildings on the east side of the farm yard, but they are evidently not in their original position, and one has a brick foundation, while the others are mounted on square stones. The stone walls on the north-east may have formed a portion of the Abbey, but it seems doubtful, for an old doorway is close to the angle of the wall. The subterranean archway from the farmyard, under the building, to the east, is certainly part of the original Abbey.

Having disposed of the additions and corrections connected with my former Paper, I have now to bring forward some further observations made during the last summer along the line of the canal, which is nearly along the same ground, but often 100 or 200 yards inland. The width of the canal when completed will be 120 feet wide at the bottom, with the sides inclining outwards according to the material composing the banks, so that when it passes through rock it will be much narrower than when clay or silt necessitate a more gradual slope. The depth of the water is to be 26 feet, and the level of the marshes will be very little above the surface. The work is carried on by means of two successive excavations or tiers. About Stanlow Abbey, for perhaps a mile, the upper tier is finished and the lower one in progress. When the upper tier has been excavated to the requisite depth, the sides are dressed to an angle of 45°, and this has been done for a few hundred yards on both sides of the canal and the strata concealed from further observation.

The Post-glacial deposits along the marshes are not exposed in a continuous section, but are divided into several basin-like depressions in consequence of bosses of rock and Boulder-clay projecting upwards at Ince, and Stanlow Abbey. The thick beds of silt and peat crop up and thin out as they ascend the slopes of the ridges referred to, and the intervening sections present a remarkable resemblance to the Coal-measures, for the beds of black peat appear like seams of coal interstratified with grey shale. The sections a little east from Stanlow Pool, and between it and Ellesmere Port, present two distinct beds of peat with silt between them, and the two beds unite as they rise and end on the slopes of rock and Boulder-clay.

The following section was taken about 100 yards west from Stanlow Cottages, which are so named on the 6-inch Ordnance Map:—

	Feet.	Inch.
Brown and Grey Estuarine Silt	6	0
Upper Peat	3	6
Grey Estuarine Silt	10	0
Lower Peat or Forest-bed	2	0
Boulder-clay	2	0
	23	6

The upper bed of peat ends abruptly 200 yards west from Stanlow Cottages. Along the Frodsham Marsh the Upper Peat is well exposed, but there are only traces of any lower bed as shown in the following section, taken about 500 yards east of the cart road leading to Ince Ferry. The Boulder-clay had, however, not been reached, so that a still lower bed of peat may be found when the excavation is deepened.

	Feet.	Inch.
Grey Estuarine Silt	9	0
Upper Peat	6	0
Grey Estuarine Silt, with the Peaty lines at the depth of 5 and 10 feet	20	0
	35	0

The Lower Peat or Forest-Bed where it rests on the Boulder-clay on Stanlow Marsh presents many stumps of trees in the position in which they originally grew, and at the place where the foregoing section was taken, the peat about each tree was somewhat higher than that between them, and a series of depressions occurred resembling the following waved line with the stump of a tree at each elevation. The thickness of this lower bed of peat varies from two to three feet.

The Lower Estuarine Silt rests on the Lower Peat, is of a bluish grey colour and varies in thickness from 10 feet in the depression to about a foot as it rises against the bosses of rock and Boulder-clay. It occurs in all the sections, but though so well exposed no shells or bones have been found.

The Upper Peat varies from one to 10 feet in thickness, being thinnest on the ascending slopes. It is sometimes divided into two beds by silt which varies from a mere parting to a band 2 feet 6 inches in thickness. So far, no upright trunks of trees have been found, but there are large prostrate trees at intervals and many fragmentary branches, stems and leaves occur in some places, just as may be seen in a recent forest or plantation.

The Upper Estuarine Silt is usually from 2 feet to 6 feet thick, but occasionally 8 or 10 feet. In some places where it appears to be 20 feet in thickness, it is probable that the Upper Peat has been denuded and both the Upper and Lower Silt are represented as one deposit. The upper portion frequently changes from a bluish to a brownish grey colour, the result of the most recent floods from spring tides, and there are indications of clay having been laid down to raise the surface. The soil is very thin, for the land seems to have been always liable to floods from the Mersey at high tides, so that there has been a continuous deposit of silt in progress down to recent times.

The sections not being completely exposed, and the portion between Ince and Stanlow Pool only just commenced, this description of the beds exposed should be considered of a preliminary character, for another final and complete section, from Holpool Gutter to Ellesmere Port, will be brought forward as soon as the excavations are more advanced.

NOTES ON A FEW BORINGS AND THE BASE OF THE NEW RED SANDSTONE IN THE NEIGHBOURHOOD OF LIVERPOOL.

By A. Timmins, A.M.I.C. Eng.

In 1882 the Cheshire Lines Committee made a borehole at Halewood, near Hunt's Cross, in search of water, situated in the centre of the triangle made by the Manchester and Liverpool and the Southport Railways; and owing to what was considered a favourable site for obtaining water at a shallow depth, the borehole was restricted in size. The following series of strata were proved:—

C.L R., HALEWOOD SECTION.

		Feet.	Feet.
Glacial Deposits.	Stiff Clay	45 ..	—
	Quicksand	10 ..	55
	Stiff Sandy Clay	38 ..	93
	Sandy Clay	2 ..	95
	Stiff Clay	20 ..	115
	Loamy Sand	4 ..	119
	Clay with small Stones ..	10 ..	129
	Sandy Gravel	8 ..	137
	Vein of Sand or Rock ..	1 ..	138
	Red Marl	276 ..	414

The Glacial deposits it will be seen were here 137 feet thick, and above the general thickness, and would show that either there is a Pre-glacial valley here with a steep side to the west and a gradual shallowing to the east, or that the harder pebble beds of the western side have resisted denuding action more than the marl.

Of the age of the 276 feet of Red Marl proved there is much uncertainty. North of the Mersey in this

locality the Keuper Marl is not known, while the Permian Marls and the clay beds of the Upper Coal Measures do not attain this thickness.

No fossils were noticed, which I do not think was surprising, because, owing to the comminuted state of the débris, it would be lucky to find fossils if they did occur. In the Permian Marls of Stockport I have found casts of fossils, and owing to the kindness of Mr. W. J. Gray, of that town, I am able to show you some of his collection of Permian fossils. No beds of Limestone were noticed, although the strata were very calcareous at times, as is shown by my analyses at 303 and 373 feet:—

	303 Feet.	373 Feet.
Insoluble Matter..	77·67	75·40
Oxides of Iron and Alumina ..	3·21	7·68
Calcium Carbonate	18·66	16·68
Magnesium „	·00	·07
	99·54	99·47

Thin beds of Limestone may have been penetrated without having come to my knowledge. In the absence of fossils it occurred to me that chemical analysis might throw some light on its age. The composition of Keuper and Permian Marls, however, varies so much that I would not care to place too much reliance upon it. After an experience of many years in analysing marls from well-known geological horizons, so far I have noticed that the Permian Marls contain less oxides of Iron and Alumina than the Keuper Marls do, the average being 3·6 °/₀ for Permian, and 13·4 °/₀ for Keuper Marl. The general colour and appearance of Permian Marl is a brighter red than Keuper, which is darker and deeper in colour. The laminæ of red and grey in the Keuper alternate so quickly at times as to

give the débris a mottled appearance when taken out of a bore-hole; on the other hand Permian Marl is extremely uniform in character and appearance. Any one, who, like myself, has had opportunities of seeing two bore-holes, one in Keuper Marl, the other in Permian Marl, both going on at the same time, and regularly visited them, could not have failed to see a remarkable difference and learnt a valuable lithological lesson.

In the hope (I am speaking now of 1882) that further light might be thrown on the difficulty by microscopical examination, I communicated with Mr. C. E. De Rance, F.G.S., of H. M. Geol. Survey, and sent him all my samples. He submitted them to the late Mr. J. A. Phillips, F.G.S., who kindly examined them, and reported as follows—

The plastic red specimen (395 ft.) is a fine clay strongly coloured by oxide of iron, and apparently contains patches of greyish "Boulder Clay." After being attacked by hydrochloric acid it became perfectly colourless, and this white residue consists of clay containing fragments of angular quartz, with a substance which is probably kaolinite, resulting from the decomposition of felspars.

The coarser sample (414) is like the former, but with a large proportion of angular quartz in fragments, varying from $\frac{1}{1000}$th to $\frac{1}{150}$th part of an inch in diameter; the clay does not appear to contain any particle of boulder clay.

From the above report it is evident microscopical examination throws no more light upon it than the chemical analysis, so therefore we must go into the field, where again we are very much puzzled, the country being so thickly covered with drift and no natural sections being exposed for a great distance. The only deep

borings then existing in the locality, were the borings at the pumping stations of the Widnes Local Board, viz.: Netherley and Bellevale, which are about 1¾ miles north, and Stocks Well 2⅔ miles to the east of Halewood borings; in these three borings of the Widnes Water Works, which are all over 500ft. deep, there is almost an entire absence of marl; the strata is principally moderately light soft red sandstone, not at all variegated, the grains of which are uniformly rounded like millet seed. This millet seed grained appearance has been looked upon as characteristic of the Lower Bunter sandstones; but this is however not quite so: from the samples I exhibit, it will be seen that both Upper Bunter and Permian sandstones have this appearance. The Permian sandstones in the Stockport district have this peculiarity to a very marked degree; in the Upper Bunter the rounded grained sandstones occur in bands, and where these bands occur the sandstone is less loamy, which loaminess, is, I consider, one of the marked characteristics of the Upper Bunter.

So far we see that the age of the strata in which these Widnes Local Board wells are sunk is uncertain. Fortunately, at this period, a deep boring was made by the L. & N. W. Railway Company to the east of Prescot, at Portico Lane Bridge, on the Huyton and St. Helens Branch Railway; and here again we are carried into uncertain ground. Instead of meeting with pebble beds, as the surface indications would point out, the following section was proved:—

L. &. N. W. RY. CO.—PRESCOT SECTION.

	Feet.	Feet.
Red Sandstone (m. s. gd.)	54	.. —
Red Sandy Marl	41	.. 95
Fine Red Sandstone	19	.. 114
Red Marl	11	.. 125

	Feet.	Feet.
Light Red Sandstone	35	.. 160
Red Marl	2	.. 162
Light Red Sandstone	33	.. 195
Fine Darker Sandstone	20	.. 215
Coarse Red Sandstone (m. s. gd.) ..	366	.. 581

Here we have strata similar to the Widnes wells, but if possible, more Permian in character. The analysis of a sample at 54 feet shewed:—

	Per cent.
Insoluble Matter	83·59
Iron Oxides and Alumina	3·46
Calcium Carbonate	9·90
Magnesium „	0·91
	97·86

The sample at 54 feet is both chemically and lithologically similar to a sample from the Liverpool Corporation Bootle well at 1,290 feet, the analysis of which gave:—

	Per cent.
Insoluble Matter	76·69
Alumina	7·71
Iron Oxides	1·03
Calcium Carbonate	10·63
Magnesium „	1·44
	97·51

About a mile to the south lies the Whiston inlier of Coal Measures, and almost midway between is Holt Lane Quarry, in which good pebble bed sandstone is quarried, the strata lying at the high dip of 25° west. In this quarry a bore-hole was made, 165 feet deep; 130 feet was undoubted pebble beds, the lower 35 feet of sandstone displaying the millet seed grained appearance. This bore-hole is to be deepened ere long, and its future depth will prove very interesting. It is evident this quarry is faulted in between the Whiston inlier and Prescot Railway boring, the base of which cannot be far

above the Coal Measures, which are seen occurring three times in the railway cutting towards Prescot Station. These are thrown up by a series of strike faults, which would appear to be parallel to the Thatto Heath anticlinal fault. Between Thatto Heath fault and this Prescot boring there would appear to be another fault, with probably pebble beds faulted against the soft beds of Prescot sandstone. A boring at the entrance to Thatto Heath deep rock cutting, Eccleston Summit, showed the following section:—

ECCLESTON SUMMIT SECTION.

	Feet.	Feet.
Loamy Soil and Stones	20 ..	—
Red Loamy Soil	13 ..	33
Fine Red Pebbly Sandstones	10 ..	43
Salmon-coloured Marl..	2 ..	45
Sandstone	4 ..	49
Red Marl	5 ..	54
Fine Red Sandstone	7½ ..	61½
Red Loam	9½ ..	71
Light Red Sandstone	3 .	74
Red Marl	6 ..	80
Fine Light Red Sandstone	13 ..	93
Red Loam	23 ..	116
Fine Red Sandstone	54 ..	170
Grey Marl	5 ..	175
Coarse Greyish Sandstone & Pebbles	6 ..	181
Fine Red Sandstone	5½ ..	186½
Red and Grey Marl	3½ ..	190
Fine Light Red Sandstone	41 ..	231
Loamy "	16 ..	247

There is nothing unusual about this section, it being quite a usual pebble bed series.

The Prescot cutting was described by Dr. Ricketts, F.G.S., in a paper read before the British Association at Liverpool, September, 1870. The sandstone shewn Lower Bunter, in Dr. Ricketts' paper, is to be seen lying upon purple shale, which at its junction with the sand-

stone throws out a copious spring of water highly charged with Ferrous Carbonate, which oxidising, lines the drains with ochreous matter. I made a section of this cutting in 1880, but as the banks had got turfed over I did not see it to the same advantage as Dr. Ricketts, so my section will be somewhat different and not so complete. So far we have not proved the age of these sandstones, and only see that in this area the action of faults has been very marked, and that the soft red sandstone is to be seen in all cases lying upon the Coal Measures.

The next boring in this locality was made the beginning of last year at Childwall Vale, for the Liverpool Corporation Waterworks: this you will see on reference to the 6 inch map, lies about 500 yards from Bellevale, and 1,100 yards from Netherley borings, and almost in a direct line between the two. The section proved here:—

GATEACRE BRIDGE SECTION.

	Feet.	Feet.
Clay and Gravel	8 ..	—
Light Red Sandstone	170 ..	178
Grey ,, ...	15 ..	193
Light Red ,, ...	4 ..	197
Grey ,, ...	22 ..	210
Hard Red Massive Sandstone	54 ..	273
Grey Marl	1½ ..	274½
Fine Red Sandstone	19½ ..	294
Coarse Brown Sandstone	10 ..	304
Hard Red Massive Sandstone	38 ..	342
Fine Grey ,, ...	3½ ..	345½
Dark Red ,, ...	23½ ..	369
Very Fine Red ,, ...	57 ..	427
Grey Sandstone, with Pebbles	6 ..	433
Dark Red Marl	1½ ..	434½
,, ,, Sandstone	½ ..	435
Dark Purple & Grey Saponaceous Marls	5½ ..	440½

Here again the section is totally different from what was thought to be quite a certainty. We have undoubted Pebble Beds resting on Coal Measures, and it is very evident that this boring is in a tongue of sandstone faulted in between the Netherley and Bellevale borings, and that these faults are not very porous, and shut out the underground water that finds its way to the Widnes Wells in such vast quantities.

Through the courtesy of Mr. D. M. F. Gaskin, M.I.C.E., Engineer to the St. Helens Corporation Waterworks, I am enabled to give you the sections of the Knowsley and Kirby pumping station wells and bore-holes, which were only completed last month; these are north of what we have been looking at.

KNOWSLEY WATERWORKS SECTION.

		Feet.	Feet.
Pebble Beds.	Surface Soil and Sand	3	—
	Brown Marl	3	6
	Red and Yellow Marl	3	9
	Red Sandstone	6	14
	Soft do.	42	56
	Red do. veins of yellow ..	72	128
	Close Grained Sandstone, veins of yellow	33	161
	Close Grained Sandstone, without veins	28	189
	Gritty Grey Sandstone	9	198
	Red Marl	1	199
	Red Sandstone	27	226
	Red, with veins of Calcite ..	6	232
	Red Sandstone	25	257
	Red do. close grained ..	1	258
	Red Marl	3½	261½
	White Sandstone	6½	268
	Grey do.	3	271
	Red and White Sandstone ..	22	293
	Red Marl	1½	294½
	Coarse Red Sandstone	20½	315
	Red Marly Sandstone	20	335

	Feet.	Feet.
Red Marl	28	363
Soft Grey Sandstone	47	410
Hard White Sandstone	16	426
Fine Soft Red Sandstone	52	478
Red Sand	1	479
Soft Red Sandstone	161	640
Mottled do.	3	643
Soft Red do.	44	687

Dips 1 in 9 North.

Of this section it is questionable if we can call any of it pebble beds, most of the beds being much like those met in the Winwick and Parkside borings, and a sample at 161 feet is again similar to the bottom portion of Bootle bore-hole, which is 6½ miles west. Below this there is 426 feet of soft red sandstone similar to the Prescot beds; and Mr. Gaskin informs me that the lower portion of the boring yielded water abundantly. Where proved these beds have always yielded water freely, and it would seem that the Bootle boring had terminated just when it seemed nearest its object. What thickness these sub-Bunter beds are, I fear we shall know only by boring through them.

KIRBY WATERWORKS SECTION.

		Feet.	Feet.
Turf		1½	—
Clay		4	5½
Red Sand		2½	8
Red Sandstone		2½	10½
Yellow ,,		2	12½
Red ,,		4	16½
Red ,, coarse		3	19½
Mottled ,, with Pebbles		3	22½
Same with veins of Yellow		5½	28
Grey Sandstone and Pebbles		6½	34½
Red ,, ,,	78½	9½	46
Red ,, ,,		51	97
Red ,, ,,		18	115
Red, with White Patches		3	118
Red, ,, Pebbles		26	144

	Feet.		Feet.
Variegated Sandstone	3	..	147
Red Sandstone and Pebbles	28	..	175
Coarse Grained „	9	..	184
Red „ „	70	..	254
Variegated „	½	..	254½
Red Sandstone	7	..	261½
Variegated „	½	..	262
Red Sandstone and Pebbles	38	..	300
White „	¼	..	300¼
Red „ and Pebbles	52	..	352¼
Red Marl	¼	..	352½
Red Sandstone with bands of white Stone	40	..	392½
Soft Red Sandstone	67½	..	460

ABSTRACT OF SECTION.

Drift	8 ft.	..	—
Middle Bunter	344¼	..	352¼
Permian	107¾	..	460

This section is very interesting, as having gone through pebble beds into this underlying soft red sandstone, the lower portion having dispersed through it the small round sulphur or pyrites balls, similar to what were met with at Collin's Green, Winwick and Parkside borings. These sections and the Farnworth one are given in Mr. Morton's paper: "On the Base of the New Red Sandstone in the Country around Liverpool," read before this Society in Session 1881-82. In these sections Mr. Morton has adopted a different classification to Mr. Strahan, F.G.S., H.M.G.S., with whom I examined the sections soon after the borings were made. Mr. Morton considers the red marl begins the Permian strata, Mr. Strahan being of the opinion that the strata below the pebble beds is lower mottled sandstone.

The sandstones occurring between the marl and Coal Measures are rather abnormal in character for lower mottled sandstone. An analysis of the Winwick and Parkside sandstones shewed them to be very calcareous, and the Winwick contained 12 per cent. of Carbonate

of Magnesia. I am of the same opinion as Mr. Morton, that the red marl begins the Permian strata; and I do not consider that the lower mottled sandstone occurs in our immediate locality. If we trace the New Red and Permian from Stockport through Ardwick, and along the southern borders of the Coalfield from Manchester to Liverpool, it is very questionable if we can say where the lower mottled sandstone comes in. Besides, the composition and appearance of the intervening beds are, if you call them lower mottled sandstone, abnormal; their calcareous and magnesic nature being more in accordance with Permian strata. That the Permian strata is liable to rapid variations in thickness, owing to overlap and unconformability, has been pointed out by Professor Hull, M.A., F.G.S., H.M.G.S. An interesting section of the penetration of middle Bunter and Permian occurs at Openshaw, near Clayton, Manchester.

	Feet.	Feet.
Drift	36	—
Bunter Pebble Beds	46·2	82·2
Permian Marls and Limestones	200·7	285
Conglomerate, &c.	2.3	
Permian Sandstone	752	1037
Upper Coal Measures	263	1330

At Stockport, five miles south, the Permian marl is 120 to 130 feet thick, and here the pebble beds in all cases lie on the Permian marl. The Permian sandstone, as yet, has not been proved, but calculating from the outcrop it is estimated at 1,500 feet thick. Returning now to our own immediate locality, we find that the Netherley, Bellevale, Knowsley, Kirby, Bootle, Prescot, and Halewood Rectory borings are in strata similar in every respect to the Permian of Stockport and Manchester, considering that at Stockport we have not proved the thickness of the Permian sandstone; and at Openshaw we see that it proved 752 feet thick, and that in the Manchester area there are very rapid alterations

in thickness in short distances, and that in the Winwick and Parkside wells we have underneath red marl, calcareous sandstones, and the positive evidence of the development of over 500 feet of soft red sandstones underlying the pebble beds at Prescot and Knowsley, and lithologically undistinguishable from the Permian sandstone of Manchester and district, and in the absence of any positive negative evidence we are bound to call them Permian. I have discarded the idea of some of them being upper mottled, as has been thought, because they do not possess the loamy and variegated general appearance of the upper mottled sandstone, with which I am very well acquainted, as they are very much developed at Runcorn; and in a boring I superintended at Ashmoor, near Runcorn, it was bored into 515 feet without its base being proved, the boring commencing at a level 150 feet below where its top is exposed at Halton, thus shewing that it cannot be less than 700 feet thick.

I will now return to where I commenced, and will draw your attention to the cross sections. If we refer to the 1-inch geological map, we shall see that the pebble beds of Woolton and Speke are shewn dipping east, and in the absence of any break or fault should be found in the Bellevale and Halewood bore-holes. This has been proved to be not so, and it is evident there occurs a large north and south fault, which is probably a continuation of the Croxteth Park fault, through Roby Station, and which divides a little further south, and throws the Gateacre and Halewood borings in between trough faults. The contour of the country favours this view. We still have to face the fact that the Halewood marl is much thicker than any section we know. This, however, may be a fictitious thickness, owing to the marl lying at a very steep angle, which is usually the case in proximity

to a large fault. The Halewood boring is further south than any that has yet penetrated the pebble beds, and it may be that we shall find the Permian marl coming in as we get further south. A boring at Hale, three miles to the south, would seem to further this view.

VINE COTTAGE SECTION, HALE.

	Feet.	Feet.
Turf and Soil	4 ..	—
Soft Red Sandstone	64 ..	68
Fine Bright Red Sandstone ..	100 ..	168
Red Marl	67 ..	235

Here the red marl was not probed, but judging from experience of pebble bed marls, this would be very much thicker than any I know of. I am unfortunate in not having any samples wherewith to form any sound opinion respecting its age, but it is very probable that it is Permian marl, although the pebble beds would be very thin here, which would be remarkable considering the development of it proved at Bootle and in the Widnes Chemical Works wells. It has been bored into between 700 and 800 feet thick without being penetrated.

ANALYSES OF PROBABLE PERMIAN MARLS AND SANDSTONES.

Locality.	Insoluble Matter.	Oxides of Iron and Alumina.	Carbonate of Lime.	Carbonate of Magnesia.	Total.	Depths.
Halewood, C.L. Ry. Co...	93·07	1·31	3·66	2·24	99·28	287
"	77·67	3·21	18·66	·00	99·54	303
"	75·04	7·68	16·68	·07	99·47	373
Prescot, L. & N.W.	83·59	3·46	9·90	·91	97·86	54
Bootle, Liverpool	76·69	8·78	10·63	1·44	97·51	1290
Knowsley, W.W.	95·78	1·60	1·53	·00	98·91	170
Winwick, "	63·70	4·12	19·32	11·97	99·11	228
Parkside L. & N. W....	82·55	2·98	14,04	2·96	99·86	220
Baswich, Stafford, W.W.	80·15	4·21	14·50	·00	98·88	164
" "	84·94	4·18	8·88	1·63	99·63	295
" "	39·18	3·96	55·56	·24	98·94	425
Shrewsbury, Grammar Sch:	89·40	1·28	9·52	·00	100·20	—

NOTES ON SOME BASALTIC DYKES OCCURRING NEAR AROS, MULL.

By Joseph Lomas, Assoc.N.S.S.

Special Lecturer on Geology, University College, Liverpool.

Long ago it was pointed out by Macculloch that in the Western Isles of Scotland there exist masses of igneous rocks associated with others of sedimentary origin. Sometimes the former lie in the lines of stratification, and at other times cut their way regardless of stratification.

It is universally admitted that these igneous masses were once in a fluid state, and had their origin deep down in some great storehouse of molten rock. Water, reaching this great subterranean fiery reservoir, either by percolation through cracks or by soaking through porous strata, gets dissolved in the mass, just in the same way as carbonic acid gas is dissolved in water (soda water), or oxygen gas in liquid silver. As the amount of steam dissolved increases, the tension gets greater, and at last it may be sufficient to cause the superincumbent masses of rock to give way, and then fissures are formed which get injected by the liquid. Some of these cracks reach the surface, and the magma flows out as a lava stream. The pressure being removed the steam is now able to escape through the viscous mass, and vesicles are formed, causing the rock to be honeycombed when solid. The cooling is accelerated by the latent heat required to convert the water into steam. Owing to the rolling movement of a lava stream, it is found to be vesicular top and bottom.

The intrusive masses which do not reach the surface are sometimes exposed by denudation, and we find them cutting strata at all possible angles. Sometimes they are nearly horizontal, and are then called intrusive sheets. At other times we find them inclined, and some are vertical, or nearly so, and these are called dykes.

Intrusive sheets and dykes cooling under great pressure do not have their upper and lower surfaces vesicular, although there is frequently a line of vesicles running up the centre of the mass; and in some places where a communication exists with the surface there may be a vesicular selvage very local in character. The position of the vesicles is a very trustworthy way of distinguishing lava streams from intrusive sheets.

But why do vesicles appear in the middle of intrusive sheets and dykes?

The outer portion of the masses will get cooled first by contact with the surrounding rocks ("country"), and will solidify before any vesicles could be formed. The central portion having room to expand, owing to contraction of sides, the pressure is decreased and the steam escapes. The outer portion thus solidifying with water in it and the middle portions with less water, it would be interesting to see if there is any difference in chemical composition. This would only be possible in a very recent example, as the vesicles subsequently get filled up by the infiltration of chalcedony, calcite, &c.

The rate of cooling depends largely on the conducting power of the surrounding "country." If this is good the dyke wlil be fine-grained; but if a poor conductor of heat the mass may be so long in cooling that it becomes coarse in structure and almost perfectly crystalline. In fact in the same dyke one may often see the central portion coarsely crystalline (a dolerite, if basic),

and on each side it gets fine-grained and more glassy, passing through basalt and magma basalt to a perfect glass—tachylyte.

Glassy selvages vary from a mere film to 4 or 5 inches thick; but the same dyke may have tachylyte at one point and not at another, when it passes through rocks of different conducting powers.

Dykes, although as a rule following a definite direction, are often wavy, and the edges thus present a series of convex and concave surfaces. Where a convexity occurs the tachylyte is always thicker than at a concavity. This is because there is a greater quantity of country surrounding one than the other. Kernels of tachylyte are sometimes found in the interiors of dykes, and these it is supposed have been torn off from somewhere and floated up with the magma.

Certain structures are set up in lavas and intrusive masses on shrinking. In lavas we find as a rule vertical columns frequently hexagonal, but near the top of a lava stream the columns are often finer in texture. The columns always lie at right angles to the cooling surfaces, so in intrusive sheets and lava streams they are vertical, whereas in dykes they are horizontal, or inclined at a low angle.

In lavas the columns are not well defined as a rule, and run out towards the middle to a point.

In intrusive masses the columns are almost always sharply defined, and frequently perfect hexagons. Sometimes the dykes have lines of shrinkage running along parallel to the sides, thus giving them a banded appearance.

Intrusive sheets are as a rule very platy, and their sides subtend sharper angles than those of dykes. In dykes the columns seldom are seen with angles less than

90°, but in intrusive sheets they sometimes appear like a knife edge. Columns from a dyke or intrusive sheet may easily be distinguished by these characters.

In Mull we have an old volcano cut to its very core, and here we see the great frozen lake exposed, giving off dykes and intrusive sheets into the surrounding strata.

It was while examining these last summer along with my friend Mr. P. F. Kendall, F.G.S., of Owen's College, that the foregoing observations were made, and I am indebted to Mr. Kendall for many suggestions.

The old volcano gives evidence of emitting two classes of rocks, acid and basic, and we find dykes belonging to each class. I shall confine my remarks to those basic dykes met with near Aros. These are so numerous that it would be impossible for me to go over them all in detail. A few of the more interesting ones must suffice.

The centre of the ancient volcano of Mull was probably situated in the cluster of mountains about Beinn, Talaidh, Beinn Buy, &c., for these are in the main made up of coarse gabbro, which must have cooled very slowly and at a considerable depth. The dykes, which are numbered by hundreds, all converge to this centre.

Beginning at Pennygown about the mouth of the Forsa River, we find exposed on the shore numerous dykes pointing up Glen Forsa. The "country" from here to Salen Pier is mostly a volcanic ash rudely stratified and containing "bombs." It is a bad conductor of heat, and so we should not expect to find good tachylyte, and although every dyke was carefully examined, not a single case of undoubted tachylyte could be found. The dykes in this area have broken away from the "country," so that they have a narrow channel running alongside. Two intrusive sheets are met with

in this district, and they consist of a very fine.grained magma basalt breaking with conchoidal fracture.

About Salen Pier the country becomes more compact consisting of basalt with porphyritic felspar crystals, and a dyke just under the Pier House shows good tachylyte. Near this is a big dyke with large fresh crystals of Labradorite embedded in a fine-grained magma basalt. The same dyke is seen on the opposite side of the Bay beyond Aros Hotel, again on the Tobermory Road, and at Erray Burn beyond Tobermory. I have traced it for over twelve miles.

Going along the road from the Pier towards Salen, in a field on the left hand side is a large intrusive sheet. The country on which its rests is coated with tachylyte, and a band of vesicles filled in with chalcedony runs along the middle of the sheet. Further along Salen Bay, there are numerous dykes, mostly intrusive in an old lava stream and several have glassy selvages. The shore now for a mile or more lies parallel to the direction of the dykes, and so we meet with few before arriving at Aros Bridge, where the shore again is at right angles to the direction of the dykes.

Before crossing the Bridge, if we go along the banks of Aros River for a little distance, we find several dykes and some very fine examples of spheroidal weathering in basalt. About a quarter of a mile from the Bridge is a very remarkable dyke exposed on the river banks. It is really an example of one dyke being thrust into another, and here we find the best possible conditions for the formation of tachylyte. The glassy selvage reaches nearly three inches in the thickness, and this is owing to the good conducting power of dyke basalt.

Along the Aros shore from the Castle to Aros Hotel, we find many dykes, but about the Hotel there is a great

plexus of dykes. Further on towards Tobermory the number increases, and in some cases they seem to cross one another, and others on reaching a dyke run alongside for the rest of the way. Many give off little strings into the adjacent "country." Some divide into a number of smaller dykes. One dyke about a mile N of Aros Hotel (4 feet wide), splits up into 7 branches, some of which reunite, and others die out to nothing. It frequently happens that a dyke bifurcates, and then reunites thus enclosing "country."

Near the Kelp landing place about two miles N. of Aros Hotel, is a dyke running through beds, the lower one of which is loose amygdaloidal basalt, while the upper one is compact. No tachylyte is found on that portion of the dyke in contact with the lower bed, but it is well developed where the upper bed is in contact with the dyke. The dykes bearing tachylyte found in this area are enumerated in a paper by Messrs. Kendall and Lomas, published in the "Geological Magazine," of December, 1888.

THE VYRNWY VALLEY: ITS GEOLOGICAL AND GLACIAL HISTORY.

[ABRIDGED.]

By Sir J. A. Picton, F.S.A.

The approaching completion of the great scheme for the supply of water to the city of Liverpool from the Severn Basin, naturally calls attention to the physical aspect of the district, and to the causes of its special adaptation for the purposes now required, A few notes, therefore, on the leading features of the hills and valleys, and on the

operations of nature which have brought them to their present condition, may not be out of place.

The basin drained by the Severn contains the largest drainage area in England, extending from Merionethshire to Somerset from north to south, and from Caermarthenshire to Warwickshire from west to east. The portion drained by the River Vyrnwy, when viewed on the map, appears comparatively insignificant, but actually is capable of furnishing a very large supply of excellent water. The Cymric name *Vyrn-wy*, rapid stream, is indicative of the mountainous district from which it derives its source. It takes its rise on the southern slope of the Berwyn mountain range which divides the basin of the Dee from that of the Severn, and after a course of about twenty miles (omitting the windings of the stream) it falls into the Einion, which is an affluent of the Severn; its entire length runs through the county of Montgomery.

Above the head waters of the river the mountain range rises to the height of 2,100 feet above the sea level. There are at least four sources which unite to form the river a little beyond the village of Llanwddyn. The valley which is the site of the reservoir is nearly five miles in length, and about half a mile in width, rising from a flat marshy strath, through which the river winds, to a series of rounded heights on both sides.

This is the aspect presented by the locality; a lovely landscape offering many picturesque points of view. It is an open book in which the inquiring mind may read the wonderful operations of nature during the countless ages of the past. It is a history which cannot lie, for it carries its credentials palpably on the surface. Let us endeavour to read it aright.

The rocky strata which form the basin belong to the Silurian system, both upper and lower; the latter on the

north-east side, the former on the north-west, a fault or dislocation running along the centre of the valley dividing the two.

The action of ice has imprinted its record on the book of nature, in our own immediate neighbourhood, in a variety of ways. Within the city of Liverpool erratic blocks, some of considerable size, of greenstone and granite, have been found a few feet below the surface, imbedded in sand. One in the verge of the ancient sea margin, on the slope of William Brown Street; another on the site of Queen Buildings, in Dale Street. Both are ground to a flat surface on the lower side, and bear striations strongly marked. There is no power by which these blocks, the nearest origin of which would be the patches of igneous rock on the west coast of Cumberland, could be transported to this distance, except that of icebergs, floating in a shallow, icy sea, and grinding along the bottom with irresistible force.

Ancient ice action in another, but kindred, form presents itself in what is called the "Northern Drift." This consists of loose superficial accumulations of sand, gravel, and clay, charged with rounded subangular and angular stones and boulders, many of which have travelled hundreds of miles.

This drift débris must have been deposited under water. When the elevation of the land took place the surface acquired very much the contours of hill and valley which it has since maintained. I quote from Professor Ramsay. "Much of the land was then slowly depressed beneath the sea. As it sank its minor features were modified, for terraces were formed on the old sea margins, and icebergs drifting from the north, and pack ice on the shores, ground and grated along the coasts and sea bottoms, smoothing and striating the rocky

surfaces over which they passed, and depositing in the course of ages, clay, gravel, and numerous boulders over wide areas.

"All through Britain and Ireland this drift rises well up the flanks of the mountains. In North Wales generally and in Carnarvonshire particularly, it is very visible." The wide-sloping plain on the south-west flank of Snowdon, and a similar one on the west of Carnedd Llewellyn, are covered with the glacial drift, amongst which are found shells of Pleistocene age.

In some instances terraces are visible, marking pauses in the re-elevation of the surface.

To the glacial drift succeeded, after an interval the length of which we know not, the glacier period which had so powerful an influence on the district we are now surveying. That this action was subsequent to the drift is evident from the fact that, in some cases, as in Cwm Llafar, west of Carnedd Llewellyn, the descending glacier has ploughed out hollows in the drift.

To what extent the schistose Silurian strata were covered by the subsequent Devonian and Triassic deposits which crop out eastward in Shropshire and Flint it is impossible to divine, nor is there evidence at what geological period the enormous denudation which must have taken place occurred. Our present evidence is limited to the Silurian formation, and the mechanical action of ice thereupon.

The slightest glance at the eminences surrounding the Vyrnwy Valley shows that peculiar rounded form called in Welsh *Moel*, or bald-headed. The natural fracture of the schistose rock would be sharp, angular, serrated, such as we find round the skirts of Snowdon, at Tre Vaen, and the Glydyrs. The present outline of the summits is rather that of the "*roches moutonnées,*"

or polished rocks, on a larger scale, giving that soft and pleasing outline so dear to the landscape painter. Some influence of a very powerful character must have been at work to change so entirely the natural features. The existence and gravitation of ice on a large scale will sufficiently account for the phenomena.

In every part of the world where mountains occur there are either existing deposits of snow on the summits descending by their weight and forming glaciers and ice streams, or there are palpable evidences that such has been the case in geological epochs long gone by. The mode in which this force operates differs materially, according to the nature of the strata, the elevation, the angle of the slope, the character of the outline, the distance from the sea, and other adventitious circumstances. From this arises the great difference of character in the mountain scenery of different countries. The conical aspect of the mountains of Switzerland, upheaved at particular points, presents phenomena materially differing from the snow-crowned mountain ridges of Norway, separated by long narrow fiords, ploughed down their sides by glaciers in full action, from which spring innumerable torrents, leaping, sparkling, and giving life and animation to the scene. The mountainous district on the Elbe, called the Saxon Switzerland, anciently subjected to ice action, has features differing from both the above. The strata here being of friable composition, and to a great extent soluble in water, have given peculiar features to the landscape not found elsewhere.

The features of the Merioneth and Montgomeryshire mountains partake somewhat of the character of both the Swiss and Norwegian types. The Berwyn range, which extends in an irregular line from south-west to north-east, commences near the mouth of the River

Dovey, rising at various points to the height of 2,100 to nearly 3,000 feet, finally subsiding into the valley of the Dee, near Chirk. The valley of the Vyrnwy branches off south-easterly, about midway of the range.

If we picture this district raised 2,000 feet above its present level, or, what would be the same thing, the climate chilled down to the line of perpetual snow, we can clearly trace the operation of the forces at work.

The phenomena presented to our notice are, the nature of the strata, the form of the surrounding hills, the remains of the ancient moraines, the evidences of a formerly existing lake, and the gradual change of climate through long ages to its present condition.

There can be no doubt that glaciers were formed on the upper slopes of the Berwyn mountain range. In their descent they would exercise a very powerful denuding force, evidences of which still exist. In the hollows through which they were forced they tore away the rocks at the sides, and carried down the fragments as lateral moraines. Wherever a turn in the valley presented an obstacle, a large deposit was left, which remains *in situ* to the present day.

The moraines in these lateral valleys are very remarkable, and give palpable evidence of the enormous forces at work. The grinding effect of the slowly descending glacier manifests itself in several ways. The *moraine profonde* beneath the ice, consisting of the finer grained material converted into impalpable mud and silt, is dissolved and carried out from beneath by the stream which always issues from the foot of a glacier. The larger fragments, torn from the sides of the valley, drop on the ice, and are distributed according to their size, either as lateral moraines, or as erratic blocks left behind on the melting of the ice.

The great superincumbent weight of the glacier descending from the higher Berwyn range was such as to force itself over the summits of the lower eminences, denuding the superficial strata, and giving to the hills the rounded form which they now present. The rains and frosts of untold ages have done much to destroy that smooth roundness of surface originally given, but the general aspect imposed by the grinding ice still remains.

The gradual destruction of ice-worn surfaces is a point of considerable interest. When the turf and glacier débris is removed, though the underlying surfaces of cleaved slate often retain a perfect ice polish, yet after long exposure the smoothness and finer markings disappear; and though the general rounded form remains, the surface becomes roughened and the highly inclined cleavage planes present on their edges a slightly serrated aspect.

The fragments thus carried along, on their arrival at the termination of the glacier, must either fall over or be left behind by the melting of the ice, as is plainly visible at the lower edges of the Swiss glaciers.

The section of the Vyrnwy valley at the lower end, taken in preparation for the embankment, presents glacial deposits at several points, apparently the remains of the terminal moraine. These deposits are now about fifty feet below the surface, having been covered up by the accumulated alluvial mud and silt of untold ages.

Mr. Geikie observes, "Under the slow, continuous, and enormous erosive power of the creeping ice, the most compact resisting rocks are ground down, smooth polished, and striated. The striæ vary from such fine lines as may be made by the smallest grains up to deep ruts and grooves. On the retirement of the glacier, hummocky

bosses of rock, having smooth undulating forms, are conspicuous. These have received the names of "*roches moutonnées*." Long exposed, this peculiar surface is apt to be effaced by the disintegrating action of the weather, though it retains its hold with extraordinary pertinacity."*

Where the whole surface was thus covered, the tearing process at the sides of the glacier could not be exercised. The operation was rather that of grinding, triturating into small fragments the rocky surface over which it passed, of which vast quantities were left when the ice finally disappeared. The larger masses, by their superior weight, found their way to the lowest levels.

At the juncture of the upper and lower Silurian beds a depression existed, caused probably by the dislocation of the strata. The convergence of several ice streams at this point operated like a gigantic plough, hollowing out the valley to a considerable depth, probably forty to fifty feet. Arriving at the lower end, its progress was checked by a reef of rocks, occupying nearly the site of the modern embankment. Over this reef the ice would gradually force its way until the barrier was removed. At the same time, owing to the warmer atmosphere of the valley, a considerable liquefaction of the ice was increasingly going forward. The *débris* brought down by the glacier accumulated into a moraine, through which the outfall found its way to the river below.

As the climate ameliorated the ice gradually disappeared, and its place was occupied by water. This is the case in all glacier districts. The power of denudation exercised by the advancing glacier gradually diminishes until it is stopped altogether, either by a natural obstruction, or by the moraine which it has itself brought

* "Great Ice Age."

down, and the glacier becomes a lake. In the valleys surrounding Snowdon, the lakes of Llanberis, Gwynant, Cwellyn Ogwen, Idwal, owe their existence to the operation of these causes.

In the case of the Vyrnwy the evidence of a former lake is incontestible. The flat strath forming the bottom of the valley could have been formed in no other way. If the alluvial soil were removed, there can be little doubt there would be found below many of the larger erratic blocks carried down by their superior weight from the mountain sides, and the rocks *in situ* striated, rounded and polished. Such is found to be the case in the valley of the Conway, between Trefriw and Bettws, and on a large scale in the vale of Nant Francon, at the opening of the Idwal valley, where the glacial lake, the polished *roches moutonnées*, and the remains of an extensive moraine, in which are found many enormous erratic blocks, form a combination of illustrations of glacial action of the most interesting character. The Pass of Llanberris affords a striking example of the tearing action exerted by the edge of the glacier. The ice stream here had to force its way through a narrow pass of indurated rock, the result of which is shown on a grand scale by the polished and striated surfaces of the rocks *in situ*, and the number and size of the erratic blocks torn away and left behind by the retreating glacier.

The bed of the Vyrnwy valley indicates on the surface what is going on below the glacial lakes still existing. They are all gradually filling up by the detritus brought down by the streams. The operation is exceedingly slow, but is evident and palpable. The length of time required for the ploughing out of the valley by the advancing ice, the period of its occupation, the change of climate resulting in the formation of the lake, its gradual conversion

into a marsh by the alluvial deposits, and the final consummation in a fruitful valley, even on this comparatively small scale, must have been very great.

The lake of Geneva offers an instance of a much grander character. The river Rhone, where it debouches into the lake at the upper end, is of a milk white hue, and is heavily charged with mud from the glacier. In the placid lake it settles down; the mud falls to the bottom, and has been for many ages forming an advancing delta, whilst at the lower end the water, freed from its impurities, rushes into a new channel, sparkling with the irridescent flashes due to the presence of iodine.

The denuding effect of the ice action, of course, ceased with the change of climate, but was succeeded by the very powerful action of water. There are in many of these valleys accumulations of sand and gravel which evidently owe their origin to running water, leaving behind the heavier débris of the moraines, and distributing in their course the lighter material not soluble or capable of being converted into mud. These streams must have greatly surpassed in volume their present representatives. Mr. Geikie remarks—*

"It is impossible to conceive that the masses of gravel and sand occupying the lower reaches of the valleys could be laid down by rivers like the present. Some great change has taken place since the old gravel beds were deposited. The amount of water circulating in the valleys has in some way vastly diminished."

The explanation appears to be the following:—

As the ice sheet shrunk and retired, the streams descending from the glaciers in summer time were vastly swollen by the water derived from the melting snow and ice. The great currents sweeping down the valleys carried with them the lighter angular débris which was

* "Great Ice Age," p. 243.

rounded by attrition, and eventually formed the gravelly deposits spread out on the low grounds.

The Vyrnwy valley presents very striking illustrations of this. I have already alluded to the original glacial deposits below the subsequent formations. On each side of the valley there are extensive beds of alluvial clay at a much higher level. No doubt at an early post-glacial period the quantity of water flowing through the valley, derived principally from the melting of the glaciers, must have been much greater than at present, and stood at a higher level, which would fully account for the phenomena.

The process above described, and of which the feeble remains are still in operation, has been going on for countless ages. The mills of Nature grind slowly but surely. The crust of our planet is an open book, on which is written, in palpable characters, the story of its own formation and subsequent changes. The Arctic climate of the glacial period, with its intercalation of a milder interval, may be attributed to a variety, or probably a combination, of causes, without resorting to the theory of the precession of the equinoxes, or to the variations in the eccentricity of the earth's orbit. The greater elevation of the land above the sea, bringing the line of perpetual snow down 2,000 feet, would of itself be almost sufficient to account for the phenomena.

Again, it is maintained, with considerable weight of evidence, that during the Pleistocene period the area of the Continent of Europe extended over Great Britain and at least 100 miles to the west of Ireland, bringing the fauna of the British Islands into direct communication with the Continent. This would remove to a distance the ameliorating influence of the Gulf Stream, if such a stream then existed.

The consequence of the absence or presence of these conditions is strikingly shown in the difference of climate between the coast of Norway and the west coast of the Gulf of Bothnia under the same parallels of latitude.

The above remarks may serve to aid the observer in following out the operations of Nature in shaping and moulding the surface of the earth and fitting it for the habitation of mankind.

The works now nearly completed have given a favourable opportunity for the examination of the geological and glacial features of the locality, which will well repay the investigation.

The following particulars are worthy of being placed on record :—

The length of the lake or reservoir is 4¾ miles.

The breadth on the average about half-a-mile.

The surface area 1,121 acres.

The extent of the gathering ground is—

In the Vyrnwy Valley proper	18,000	acres,
In the subordinate Valley of the Afon Cowny	3,000	,,
In that of March Nant	2,200	,,
Total	23,200	,,

The height of the surface above the point of delivery at Liverpool is about 600 feet.

The estimated supply under the present arrangement, deducting 10 millions per day for compensation water, will be 13 million gallons.

When all the projected works are carried out the supply will be increased to 40 millions per day.

The character of the engineering works is worthy of notice. The valley forms a natural reservoir, which needed little labour for its adaptation to the purpose, but the substitution of an artificial barrier at the lower

end, in place of the original reef of rock, was a work requiring great labour and skill. This has been successfully and happily accomplished, in solid masonry, with stone quarried in the valley. The huge mass of the embankment, with its long range of arches in perspective, may compare not unfavourably with the grand works of the Romans of a similar character, such as the Claudian Aqueduct at Rome, the Pont du Gard in France, built by Augustus, or the aqueduct at Segovia, erected by the Emperor Trajan.

The construction of the pipe line from Vyrnwy to Liverpool, which is the real aqueduct, with the various arrangements for filtering and purifying, equalising the pressure, crossing the streams and rivers, and the final distribution, do not come within my purview. Suffice it to say the whole seems admirably designed and successfully carried out, and will remain to future ages a permanent monument of human intelligence aiding and supplementing nature in providing for the wants of mankind.

NOTE ON THE GLACIAL GEOLOGY OF THE VYRNWY VALLEY.

By G. F. Deacon, M.Inst.C.E.*

The geology of the site of Lake Vyrnwy is of great scientific and practical interest. Having visited the Vyrnwy Valley and examined the rocks of the district in the winter of 1876–7, I came to the conclusion that the bed of alluvium—then covered by fields, morass, and

* Mr. G. F. Deacon who projected, and is now the Engineer of the Vyrnwy Scheme, was present when Sir James Picton's Paper on "The Vyrnwy Valley" was read, and by invitation of the President took part in the discussion. Mr. Deacon, at the request of the Council, has in this note written out the substance of his remarks at the meeting.

peat, stretching from the steep declivities at Rhiwargor and Eunant for a distance of four to five miles down the valley, and covering about 1,000 acres—occupied the site of a post-glacial lake. The considerations which induced this belief, and which subsequent investigations have shown to be well founded, were regarded as important in the practical use of the valley as a great reservoir. I wish to state generally what I believe to be the dynamical causes of many lake basins, and then to show their application in the particular case in question, and to explain the subsequent investigations which confirmed them.

During any great glacial period, when the whole surface of a country except its highest peaks was covered with ice—a *mer de glace*—moving slowly towards the nearest planes at lower levels or towards the sea, the ice, as in the case of an ordinary glacier confined within a valley, held embedded in its base, boulders, gravel, and sand, with which it scored and wore the subjacent rocks. The amount of such scoring and wearing away in any given time was, according to well known natural laws, directly proportional to two quantities. First, the distance travelled by the base of the ice in a unit of time, or, in other words, its velocity; second, the pressure at the base of the ice. The velocity of the base was greatest where the friction was least—high up the rounded mountain sides, certainly not in the bottoms of the deep and narrow valleys. The pressure, on the other hand, was always greatest at the greatest depths. From this it follows that the more complete the covering of ice and the greater its depth, the more must the hills have been worn down, and the less, relatively, must have been the scoring of the valleys. Towards the end of a great glacial epoch, or during a lesser epoch, when the total

thickness of the ice was comparatively small, the pressure in the valleys was relatively much greater, and the conditions were reversed: the valleys being worn more than the higher parts. Following out the period until most of the hills were above the general level of the ice, but the valleys still filled, the wear must have become almost entirely confined to the valleys; and watching the changes still further, until each glacier stretched only for a few miles, or, it may be, for a few hundred yards, along its valley from the foot of the mountain which gave it birth, the condition, as it appears to me, was reached which had caused the formation of many of our water-bearing basins from great lakes to little mountain tarns. The sketch (Fig. 1) illustrates this.

If C A were the declivity down which the glacier descended, and A B a longitudinal section of the glacier valley, there would be at A an additional pressure, equal in direction and magnitude to the resultant of the downward pressure represented by the arrow W_1, and the resistance represented by the arrow W_2. That resultant might be represented by the arrow W_3, and its pressure would be added to that of the immediately superimposed ice. It was therefore a quite inevitable result (neglecting such modifications as might be introduced by the varying hardness of the rock) that the valley would be more worn at A, that is, near the foot of the mountain, than anywhere else. At a still later stage the section would therefore be somewhat as shown in Fig. 2, where the magnitude of the resultant pressure had become still greater, and thus—until the depth of the basin was such that the friction of its sides retarded the bottom velocity—the valley would at this point be worn out at a constantly increasing rate.

Such a hollow is a true glacial basin. On the disappearance of the glacier, moraine matter partly filled

Fig. 1.

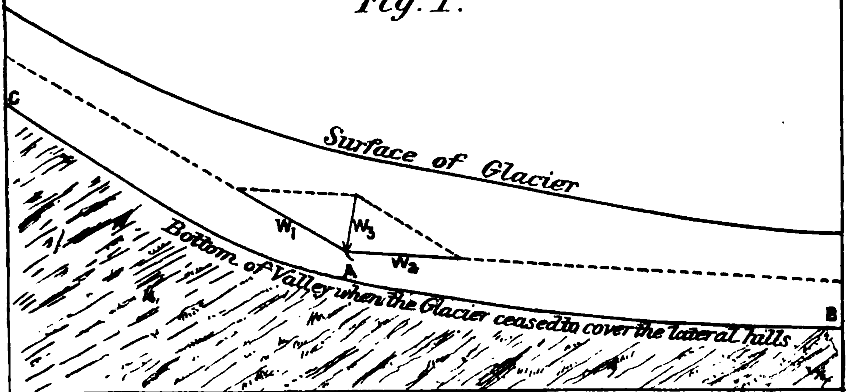
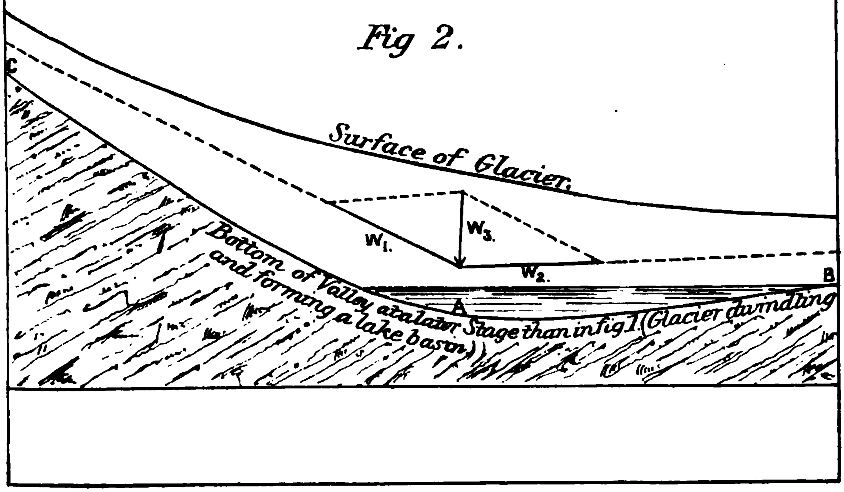

C
Surface of Glacier
W_1
W_3
W_2
A
B
Bottom of Valley when the Glacier ceased to cover the lateral hills

Fig 2.


C
Surface of Glacier.
W_1.
W_3.
W_2.
A
B
Bottom of Valley at a later Stage than in fig 1 (Glacier dwindling and forming a lake basin.)

it, and water—as indicated in Fig. 2—always, unless, as for example in some limestone formations, it drained away below. Then followed a more energetic disintegration and denudation of the mountain rocks than in our milder climate is experienced. The bottoms of the lakes, especially near their upper ends where the larger streams debouched, were more rapidly strewn with débris, which in many cases had since crept down the basin and risen above the highest bar of rock at its foot, thus forming a *strath*, now covered only in times of flood. Sometimes, owing to the existence of a large stream discharging near the centre of the length of the lake basin, the débris ultimately divided the lake into two parts as at Interlaken, between the Lakes of Thun and Brienz. Sometimes, from the same cause, the foot of the lake was completely silted up, as at Bala in North Wales, where the river Tryweryn had shortened the ancient lake at its lower end by more than two miles. In the case of the Vyrnwy basin no bar of rock was visible. The whole bottom of the valley presented a remarkably level aspect, and through it flowed the winding river. Where lateral streams entered there were deltas of somewhat higher ground, perhaps noticeable only by the practised eye, and upon the largest of these was seen the village of Llanwyddyn, 800 feet above the sea, with its church, its chapels, and its inns, around which one might draw a circle of nearly twenty miles diameter, without including a railway station. Such was the valley which by my report of 1877 was recommended to the Corporation of Liverpool as the best source for the future water supply of their City and district. In one of the plans accompanying that report the dam was shown at a narrow portion of the valley, close to the point at which it has since been constructed, in the

belief, from superficial examination, that the highest bar of rock crossing the valley beneath the alluvium, would be found there. More than three years later—when the Act of Parliament authorizing the undertaking had been passed—some 200 holes were bored down to the rock at and about the site in question. Of these, thirteen were shafts, by means of which the rock could be examined. The holes extended from side to side of the valley, and along it for a distance of about 700 yards. They were sufficiently close to enable one to draw contours of the rock, and they showed that although the shallowest rock along the axis of the valley was 45 to 50 feet from the surface, the depth both up and down the valley was much greater: so much greater indeed that a difference of an eighth of a mile in the position of the dam would have added to its cost £300,000 to £400,000.

It was thus, therefore, among other important facts, quite conclusively ascertained that up the valley from the foundations of the actual dam, the rock falls away into a deep basin, filled with alluvium, and containing at its bottom striated rocks exactly as the glacier had left them. That this basin above the site of the dam is watertight is proved beyond all question, as it now contains water to a height of 155 feet above the bar, and to suggest that in post glacial times, before the alluvium was deposited, the basin was not filled with water up to the foundation rock of the present dam, is simply to suggest that there was then a subterranean exit for the water which does not now exist. Having regard to the nature of the rock such an hypothesis is wholly untenable, and I regard it as a satisfactorily ascertained fact that, in the last post glacial epoch, the Upper Vyrnwy Valley was the site of a lake about three quarters the length of the modern Lake

Fig. 3.

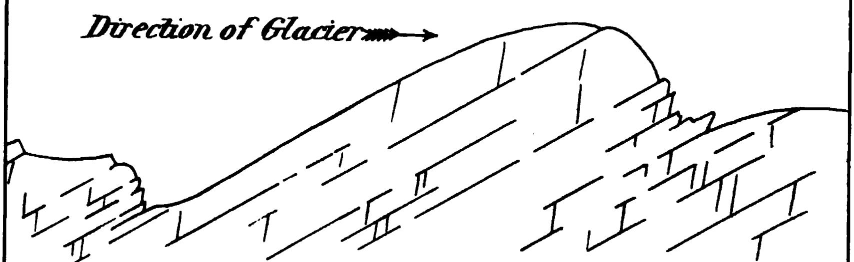
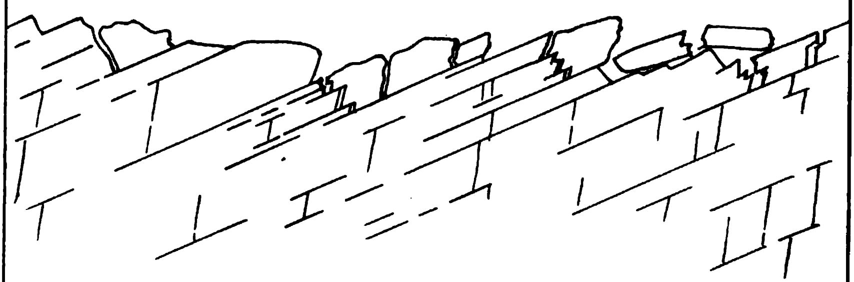


Fig 4.



SCALE.

Vyrnwy, and about 45 feet below the bed of the valley.*

For the construction of the Vyrnwy Dam a trench 120 feet wide, and about a quarter of a mile long was excavated down to the rock, across the narrow portion of the valley at which it had thus been determined to build. It rarely happens that so excellent an opportunity occurs of studying the work of ice. Figs. 3 and 4 are sections in vertical planes across the trench, in the direction of motion of the glacier. The rock is clay slate of the lower Silurian, and the dip up the valley about 1 in 2. There is a principal plane of cleavage in a nearly vertical direction at which the rock would readily divide, and the effect of this in allowing the glacier to dislocate huge fragments is very obvious from Fig 4. The loose blocks were of all sizes up to several hundred tons in weight. They were sometimes only slightly moved through spaces subsequently filled with glacial clay, and fitted exactly into the places from which they had parted. The central bed of rock in Fig. 3 had endured the dredging action better than the beds in Fig 4, and in such cases the outcrop was worn in the manner shown and much striated. Before the building of the Vyrnwy Dam was begun all rock showing the slightest unsoundness was removed, and from this cause the actual base of the dam is deeper than the borings and shafts had shown the rock to be.

NOTE.—The modern Lake Vyrnwy is now—June, 1889—within ten feet of its highest level, and has already a depth to the alluvium of 74 feet, while the hydrostatic pressure against the great dam is equivalent to that of a column of water 155 feet high. The old village of Llanwyddyn and the other buildings in the valley have been submerged for some months. The lake is remarkably picturesque, and conveys no impression of newness. It is indeed difficult to realise the fact that in its present form it is not of ancient origin.

* After the publication of the Report of 1877, I had the advantage of being accompanied over the ground by the late Director-General of the Geological Survey, Sir Andrew C. Ramsay, who entirely concurred in the view stated.

SLICKENSIDES AND NORMAL FAULTS: THEIR CHARACTERISTICS AND CAUSE.

By T. Mellard Reade, C.E., F.G.S., F.R.I.B.A.

As several of the members of the Liverpool Geological Society have been studying the numerous faults and slickensided faces to be found in the Triassic sandstone of the neighbourhood, I thought that it might help their work if I were to put my own experiences together.

The slickensides found in the New Red Sandstone are mostly distinguished by possessing, where unweathered, highly glazed porcellaneous faces, upon which striæ or flutings are plainly distinguishable. These striæ may be roughly divided into the vertical and horizontal, with deviations therefrom within certain limits. The horizontal striæ mostly follow the direction or dip of the beds on which they occur: that is to say, there is a rough parallelism with the bedding, whether the plane of the slickenside cuts the dip-plane at right angles or obliquely. Some of these faces are very highly glazed, but as to the extent of the lateral movement required to produce them we are much in the dark.

The vertical slickensides are on planes at various angles to the bedding planes, and to the horizon, and the striæ upon them, though generally following the "hade" of the fault-plane, are occasionally oblique to it. In the case of these vertical slickensides we are often, but not always, better enabled to tell the throw, the difficulty of making the estimate usually arising from the absence of well marked zones in the sandstone.

A very pretty case was pointed out by our President, Mr. Beasley, in which a number of white clay galls

cut by the fault in the Keuper sandstone of the Lingdale Quarry, at Oxton, actually pencilled the throw upon the opposite faces of the slickenside.*

From this example it would appear that a throw of six inches is sufficient to produce a fairly slickensided face; whether this has been done by one throw or a series of vibratory rubbings there is little evidence.

As to the relative age of the vertical and horizontal faults we have hitherto been able to get little or no evidence, and this is a point that should be kept constantly in view by observers in the field, that the omission may be eventually supplied.

So far as my experience goes there are many more examples of slickensides to be found in the Lower Keuper sandstones and the softer sandstones of the Bunter than in the building stones of the Bunter, usually called the pebble-beds, and I believe this applies to other districts besides our own. The explanation of this peculiarity I purpose to discuss at a future time.

Some slickensides, where infiltrated with calcareous matter, occur in laminæ, which can be separated from each other, the striæ being distinctly marked on each. So far as my experience goes it is not common for the quartzose slickensides in the Triassic rocks to be laminated.

The more perfect examples occur as single opposed faces in close contact. There are, however, occasionally to be found pieces of rock forming part of the fault striated on several faces. I exhibit an angular piece of well fluted rock to illustrate this. Another peculiarity, I believe,

---

**See* —"Some irregularly striated joints in Keuper sandstone of the Lingdale Quarry."—Proc. L'pool Geo. Soc., 1887-8, p. 387.

common to all the more perfect quartzose slickensides is the bleaching the rock has undergone for a certain depth from the face by which the peroxide of iron coating the grains is removed.

In some cases, as on one of the faces of the example I exhibit, this bleaching has only been partial, while on the other face it penetrates the rock about half an inch.

An examination with a hand lens of a partially weathered face generally reveals some of the original grains of the rock polished on the face, and surrounded by a matrix more susceptible to weathering.

In order further to study the structure of the glazed face I have had several micro-slides cut. The effect by transmitted light is very pretty. It is a transparent micro-mosaic, in which the original grains, both irregular and rounded, are embedded in a crystalline setting of what might be taken for minutely-rifted glass, but which really is, I believe, the minute angular fragments of the broken grains produced by the grinding of the walls of the fault against each other.

In order to discover the effect of this grinding action I have tried to imitate it on a small scale. The experiments were as follows :—

Experiment No. 1.—I took two pieces of fine grained quartzose sandstone (Carboniferous), measuring 3½ inches long each, and having cross sections 1⅝ inches by 1 inch. One of these was placed in an angular wooden trough formed of two pieces of pine boards placed at right angles to each other, being of the shape of what is known as "angle iron." Upon this I rested the other piece of sandstone and secured them together, and to one of the sides of the trough, with a cramp in such a way as by applying a powerful joiners' cramp to the

ends I could grind one against the other by screwing up the cramp, which was done slowly. Two pieces of pine were placed between the head of the holding cramp and the top stone, the cramp being loosened from time to time to allow for the displacement caused by the lateral movement.

The effect after a few repetitions was to grind striæ on the faces of both stones and to fill the interstices of the grains with a fine flour of the rock, making the rubbed faces smooth to the touch. The stones had been originally prepared by a mason, and rubbed smooth; but the "slickensided" surface lost the hard granulated feel of the original surface.

Much of the "flour" could be brushed off, and I show it to you in a glass tube, but some remains in the interstices that could not be removed with a dry brush. If we could leave this flour between the two faces, as in nature, subjected for a lengthened time to the action of water containing small quantities of carbonic acid, I have no doubt that the minute grains, or flour, would become cemented together, and crystalline or porcellaneous like the slickenside skin shown in the micro-slide. That ordinary rainwater dissolves silica we know conclusively by the fact that all river-water contains it, and by the way in which hard quartzites are weathered. Also by the secondary quartz which often envelopes grains of sandstone. The finer the "flour" the more rapid and effectual would the cementing become. It is quite evident to me that these slickenside faces are not due to fusion by attrition, as has been not unnaturally supposed by some.*

* "Remarks upon some specimens of slickensides from the Millstone Grit, near Todmorden," by J. Aitken, F.G.S. Trans. Man. Geo. Soc, 1873-4, p. 45.

The removal of the coating of peroxide of iron in the case of some red sandstones, is additional evidence of the action of acidulated water.*

The second experiment I made was on two pieces of Irish black marble (unpolished, but smooth.) The surface in this case became covered with a fine impalpable flour, which caked together and showed well marked striations. The surface of the rock seemed to flake off in places, but on removing the cake of flour the striæ on the face of the limestone or marble were found to be rather irregular. A repetition of this process combined with percolation of water as in nature, I believe would produce the lamellar striated skin found coating slaty and calcareous slickensides.

The difference between the rubbing done by a mason to surface the stone, and the slow movement in my experiment, is in the pressure applied. The first process removes all superfluous grains to create a surface while the latter partly shears them, and crushes the fragments into splinters.

In some cases in nature we find the laminæ of the slickenside partly replaced by carbonate of lime or baryta, another evidence of infiltration as against fusion. Slickensides, we may therefore affirm, are produced by the attrition of two rock surfaces under great pressure, and the after hardening or crystallization of the friction products by slow percolation of water, or perhaps it would be more correct to say through circulation of moisture by capillarity.

* Since this was written, Dr. J. Shearson Hyland has kindly examined some of these slides for me, and I append his description (see description of slides No. 4 (1 h) and No. 3 (1 m) from which it will be seen that, in his words, the "ground mass consists of small splinters of quartz and a little amorphous silica." He confirms the views I have here set forth.

In illustration of these views I exhibit specimens of a slickenside on the bedding plane of the slate rock of the middle quarry at Llansaintfraid, Glyn Ceriog, about four miles from Llangollen. The dip of the bedding planes is about 20° north, and the striæ upon it dip about 18° north by west. It was a splendid slickenside over a large area, and I split off a big flake. An examination of this hand specimen shows a foliated lamellar arrangement of slaty matter and of carbonate of lime. Through a thickness of about one inch lamellæ occur, the upper surface of this specimen being the most distinctly striated, the under appearing more as if polished with "black lead." The striæ seem to be repeated through the first quarter of an inch of thickness, giving the appearance as of woody fibre. This is a very common structure in slickensides of slaty rocks. The rock has evidently been ground and crushed into powder, and the carbonate of lime has infiltrated along the plane of movement. I have had two slides cut from this specimen, one parallel to the slickenside plane, the other at right angles thereto. Dr. Hyland reports that there is evidence of great change having occurred. The quartz has been broken up into smaller grains no longer in optical continuity with each other, the granulation having resulted in the formation of a quartz mosaic. The black matter is probably partly carbonaceous. In the slide cut at right angles to the plane of slickenside the light bands consist largely of calcite, but quartz granules are also frequent. The veins which pierce the black mass are formed of quartz granules. (See Appendix; slides 4*a* and 4*b*.)

I also exhibit a similar foliated slickenside from Craiglas, Aberystwith, only on a smaller scale. The rock is not affected by slaty cleavage, but has the

constitution of a gritty slate. Our lithological vocabulary seems very limited when we have to call such dissimilar rocks as Millstone grit and Aberystwith grits—"*Grits*."

I also exhibit a specimen slickenside from Morben Slate Quarry, Machynlleth. This is very interesting in consequence of the large development of rutile needles, which are seen plainly with a ¼-inch objective. They lie mostly in the planes of cleavage, as shown in the cross section (slide 2*b*), but in the slide cut parallel to the slickenside plane (2*a*), which is the same as the cleavage plane, the needles show in a felted mass crossing each other at all angles. The portion of the slate immediately under the striæ for about one-eighth of an inch thick, forms a light band in slide 2*b*, and in this the needles are more plainly seen. Judging from the hand specimen I should say that this part had undergone molecular alteration, though Dr. Hyland can find no signs of granulation and crushing. It will be interesting to know whether these rutile hairs are as largely developed in other parts of the rock, and this I hope to know before completing my investigation.

The specimens 3*a* and 3*b* are from a calcareous sandstone at Deganwy, the same rock, I believe, that Conway Castle is built of, and of Silurian age.

The movement does not appear to have had any effect on the rock below the surfaces of the slickenside.

A careful examination of the Triassic sandstones has shewn me that the "building stones" distinguished by masons who have to work them as "gritty," are so, more by reason of the development of secondary quartz than by the original greater angularity of the grains. A good building stone among the Triassic sandstones is distinguished by the way it sparkles in the sun, and an examination under the microscope reveals crystal growths

upon the quartz grains as first pointed out by Sorby, and afterwards described by J. A. Phillips.* Thus the Keuper sandstone used for building purposes from Guest's quarry, Runcorn, is differentiated from the bright red Upper Bunter rock upon which it rests and the bright red Keuper above, not only by the greater irregularity of the grains, but by the aggregation of crystalline quartz giving it its sparkling appearance. The Upper Bunter here is composed of grains that are extremely rounded and may be described as micro-pebbles, they do little more than touch each other, and they may be only cemented by the hydrate of iron.

The bright red Keuper overlying the building stone is very like the Bunter already described, but is not so friable, and the grains are not so perfectly rounded.

I could perceive no development of secondary quartz in either, though as Dr. Hyland observes, there may be some cementing silica. In the case of a rock of this sort becoming slickensided, the grains get crushed and sheared and the interstices filled with splinter dust as already described. I have seen cases where the slickensided face is quite porcellaneous and the rock itself nearly as crumbly as the Upper Bunter of Frodsham.

If we observe the weathered surface of a slickenside we shall see that the "ground mass" decays and becomes more opaque, while many of the quartz grains remain quite translucent.

Evidently the minute interspaces between the splinter dust gives admission to the decomposing agent, so that what first led to the cementing together of the ground mass now helps its dissolution.

* See also, "The Microscopic Character of the Triassic Sandstones of the country around Liverpool."—G. H. Morton, Proc. of L'pool Geo. Soc., 1884-5, pp. 52-73.

It is an interesting question as to when the hydrate of iron which coats the grains of the red rock was introduced, whether at the time of deposition or afterwards. It certainly seems to act as a preventative of crystallization so that in some cases it must have infiltrated at an early period of its history. I have often noticed, as no doubt many others have done, that the quartzite pebbles embedded in the Bunter sandstone sparkle brilliantly in the sun, and an examination reveals the fact that it arises from a deposition of small crystals of silica upon them, another evidence of the changes that take place in the rock.

The remarkable porosity of the Triassic sandstones, some of them holding as much as 3 quarts of water to the cubic foot* practically makes a multitude of "drusy" cavities in which crystallisation takes place.

The Cause of Faulting.

But how is this movement and pressure produced in Nature? Perhaps I can in this case, as I have done in many others, illustrate a geological phenomenon by the behaviour of moist sand. I have frequently observed on the shore where the sand dunes have been cut into by a high tide, and the faces left vertical, that a slip takes place. The bedding of the sand is often, as I have explained elsewhere,† beautifully developed on these faces after a little weathering. The exterior face slips bodily downwards and breaks into fragments, but these fragments are frequently large enough blocks to preserve the structure intact, even after the fall has taken place. The face of the slip or shearing plane is

* See "Experiments in the Circulation of Waters in Sandstone." Proc. of L'pool Geo. Soc., 1883-4.

† "A mechanical cause of the Lamination of Sandstone not hitherto noticed."—"Nature," Jan. 5th, 1888, p. 223.

often very true, and upon it vertical striations frequently are seen, simulating in a very remarkable manner what we see in slickensides.*

I believe that this is the whole case in a nutshell. Grains of sand cohere when damp, but so slightly that the shearing force required is small, thus the phenomenon of faulting, which can only take place on a large scale in consolidated rocks, happens in damp sand on a small scale. As bearing upon this question I have attempted the compression of moist sand in a trough in the same way that the experiments in clay, given in plate XLII. and pp. 331-3, in "The Origin of Mountain Ranges," were carried out; but moist sand, if unweighted in the trough, invariably *shears*, acting precisely like a rigid body, whereas the layers of clay fold in anticlinals.

Having now discussed the phenomena from observation, the question as to how these rock movements came about naturally suggests itself. It is not my intention to deal with thrust-planes and reversed faults, which admittedly are due to lateral pressure, in whatever way that lateral movement may be caused. The ordinary or normal fault is due to a vertical movement, either an upthrow or a downthrow. Geological text-books are somewhat vague on this question, correctly reflecting, I suppose, the cloudiness of mind that generally prevails. The origin of faults is so related to that of folding, and the general question of the formation of mountain

* Faults in the drift have been noticed by several geologists. See "Faults in Drift Gravel, Hitchen." Salter, Geo. Mag. for 1866, p. 372, also p. 572; and for 1867, pp. 37, 89; and "Faults in Drift Sand" at Rochdale Hall, p. 183. Small Faults in drift sand underlying boulder-clay are figured by me in the Q.J.G.S, 1884, p. 268, and I have seen them also in drift in a limestone district. These have all probably been produced by local slipping to fill up vacuities caused by the removal of chalk or clay from below, and not from "upheavals" as some writers suggest. Boulder-clay suffers from erosion or semi-solution by underground water, somewhat in the manner of chalk, but to a more limited extent.

ranges, that it is impossible to discuss the one without referring to the other.

It is generally conceded by geologists that normal faults occur in such a way as to suggest that the strata have been drawn apart, the intermediate portion breaking up and fitting together again so as to close up the opening. It is pointed out that if the faulted pieces were replaced in stratigraphical position, they would not fill up the same horizontal area. Now I think it will be conceded that any theory which is called in to account for one phenomenon should not be inconsistent with other related phenomena.

This is why I say that normal faulting must be considered in connexion with the folding and lateral pressure the earth's crust has certainly undergone. If we invoke the aid of machinery capable of producing the one, it must not be of such a character as to be inconsistent with an explanation of the other.

This appears to me one of the strongest arguments against the view that the corrugations of the earth's crust are due to the shrinking of the nucleus and consequent repacking of the crust into smaller and smaller spaces—the dried apple theory, in fact. It must be constantly borne in mind that this repacking cannot possibly take place by periodical convulsions, but must result from a continuously acting force, for the lateral pressure caused by the gravitation of the crust on this hypothesis is so enormous that it would be impossible for it to accumulate for a lengthened period. Even though such accumulation could take place, there would be no reflex or opposite movement by which strata could be drawn apart so as to create normal faults, which are found thickly ramifying through the earth's surface crust in every clime and every strata. This for a long time

has seemed to me to put the "contraction" theory of mountain formation out of court, for it is inconsistent with the presence of normal faults, and normal faults are as great a fact, though not as obtrusive to the eye, as mountains themselves. It has been lately shown that the contraction of the earth produces in the cooling mass much more tension than compression; that in fact the outer rind subject to compression is only a few miles deep, shading off to zero at the "level" or "shell of no strain," while all the contracting portion below to a depth of several hundred miles is in varying degrees of tension, or rather would be, were it not squeezed out by the gravitation of the shell above by a process I have named compressive extension.*

Here is a grand chance for a new theory of normal faulting! for we have only to assume that the readjustment of the crust takes place by faulting, and the thing is done; unfortunately we should then be in another dilemma—we could not account for our mountains!

What known force is there capable of drawing strata apart and rifting them so that the fragments shall fall together and re-fill the void? The pushing up of the core of an anticlinal may make a rift in the surface-rocks above, but they cannot close up again, neither do we find normal faults only on the summits of anticlinals, rather they are distributed over the undulating plains. The most compressed and folded rocks, as a rule, are freest from them. It has been suggested, and such an explanation finds a place in text books, that the wedge-shaped blocks of which strata rifted by normal faults are composed, are fitted together again by the blocks having

* "Origin of Mountain Ranges," 1886, chap. xi., and various papers, by Rev. O. Fisher; and by myself, Phil. Mag., 1887-8. "On the Distribution of Strain in the Earth's Crust."—Davison. Trans. of Royal Soc., 1887. "Physical Theories of the Earth."—Mellard Reade. *American Geologist*, Feb., 1889.

the largest bases being pushed up from below. This may account for the fitting together, but does not explain the original rifting. Several attempts have been made to show that faulting is caused by upheaval. Mr. J. M. Wilson*, treating the question geometrically, arrived at the conclusion, and many others agreed with him, that faults are "the inevitable result of the *elevation* of a curved surface," while contortion is produced by the *depression* of a curved surface, and Beete Jukes in his Manual of Geology has given much the same explanation of faulting. The faulting even on this theory is still the result of DOWNTHROW, but in order to get horizontal space for the blocks to slide in, the rupturing of the strata by elevation has to be invoked.

The author, however, is silent as to how the space below is to be obtained for the blocks to drop into. The cause producing the required elevation is antagonistic to downthrow faulting for the protuberances of most elevated portions of the earth's surface must be filled with, nay caused by, solid matter in a state of compression.

To invoke, in every case, an expanding semi-fluid sheet below for the blocks to settle into, would be losing touch with Nature altogether. The theory also has the fatal defect of being based only on hypothetical vertical elevatory movements dissociated from lateral pressure, such a phenomenon as I venture to affirm is unknown in the physics of the earth's crust. The extraordinary disregard by the older geologists of everything but vertical elevation has kept back geological dynamics for a lengthened period, lateral pressure and any other manifestation of force being looked upon by them merely as secondary effects of elevatory movements.

* Geo. Mag., 1868, pp. 205-8.

Poulett Scrope, whose researches so greatly advanced volcanic geology, in a letter* called forth by Mr. Wilson's paper, looks upon the strata affected by elevation or depression as a bent beam having a neutral axis, compression taking place on the under side and tension on the upper in cases of elevation, and the reverse in cases of depression, causing rents at right angles to the dislocating force into which, if they reached to a sufficient depth, the fluid matter of the earth might be forced. But it does not seem to have occurred to him that the causes producing elevation will affect the earth's crust in a great variety of ways other than these, and that though the effects pointed out may, to a limited extent, happen, they do not account for much more that we see in this connection. It is a striking instance of the crude ideas prevailing on such questions. One of my reviewers has called the theory put forward by me in the "Origin of Mountain Ranges," the "Scrope-Babbage" theory. It so happens that I was not aware at the time the book was published that Scrope had written on the subject of mountain building, but I am pleased to find that some of the views therein enunciated were held by so great a man, though in a very immature form. It is as difficult to trace the origin of ideas as the origin of mountain ranges, and perhaps not so profitable. The germs of every systematic attempt to explain the operations of Nature can always be found in previous writers, and indeed one may almost say in the "Ancients." It is, however, hardly necessary to point out that the first shadowy suggestion of a cause is a very different thing to a systematic theory. The following view, as to faulting, it will be seen differs entirely from that held by Scrope, and is an integral part of my theory of the "Origin of Mountain Ranges."

* Geol. Mag., 1868, pp. 339-41.

A very careful consideration of the whole phenomena of folding and faulting has led me to the firm conviction that they are both due to the same cause, namely, local variations of temperature in the earth's crust. The folding represents a rise, or is the accumulated effect of a series of rises of temperature, while normal faulting represents a fall, and is the accumulated effect of a series of falls of temperature. This theory has the merit of being consistent with observation. If we examine any geological section, we shall see that nearly always the normal faulting has been posterior to the folding, for the faults cut through the folds, excepting in those cases where the unconformable basal strata are exposed to view, in which cases no doubt both folding and normal faulting have affected the strata at previous periods of their history, and have been superimposed upon each other at various times, so that the after squeezing and faulting they have been subjected to greatly complicates the geology, and doubtless leads to those very conflicting opinions that prevail as to the interpretation of the earlier rocks.

A local rise of temperature increases the bulk of that section of the earth's crust where it happens and produces *cubical* compression. A fall of temperature in the same way decreases the bulk of the rock mass where it occurs. The difficulty most people feel, and it is a perfectly natural one, in accepting this explanation of the contortions and fractures of the crust of the earth, is that the amount of contraction or expansion seems so very little. We must remember, however, that in relation to the whole globe, we are only like ants on a ten-acre field, and every little inequality becomes magnified as measured by our little selves. If we put the question to the test of calculation, as I have done, I

think we may satisfy ourselves of the competency of changes of temperature to produce the results we observe.

That these changes of temperature occur on an enormous scale we may see by the emission of such masses of basalt in Tertiary times as distinguish the North of Ireland and the Western Islands of Scotland, by the enormous area covered by the Deccan traps in India, which are considered to be Cretaceous, and by the later enormous outflows in the Western Territories of the United States. We may rest satisfied that the temperature of the earth's crust in these areas experienced a rise throughout, and if instead of the outflows of molten matter taking place it had been sealed up by a great weight of sediment we should have had mountain-making by folding instead of mountain-building by emission, an essentially different process. In whatever way the interior forces caused by a rise of temperature manifest themselves, whether by extravasation or by compression, the results of the slow after-cooling are essentially the same, leaving the strata rifted by normal faults, due to contraction and the unequal settlement yet close-fitting together of the wedge-shaped masses of strata into which it is divided by shearing. It must not be lost sight of that every theory of mountain formation yet given to the world is based upon changes of temperature. The "contraction" theory is dependent upon slow secular cooling, and if examined quantitatively will be found to be the most wasteful machinery that could well be devised for producing the desired effect. For instance, the shell in compression as we have seen is not more than five miles thick according to the maximum calculation, and is more likely not much over two miles thick.

To produce this shell of compression the strata and underlying matter of the globe have had to cool in a decreasing ratio to a depth of several hundred miles, such cooling being distributed over a time estimated at from 100 million years upwards! If any engineer had devised such a wasteful machine for making mountains he would have been justly ridiculed.

Assuming that the earth is cooling in the way generally supposed, in what way can the escaping heat be utilised in the form of work? We have seen that the compression produced by cooling is extremely small, compared with the mass of matter cooled.

Let us consider the effect of the laying down of sediment on a particular section of the earth's surface. If this be regular and continuous for a lengthened period, the sediment eventually reaching a thickness to be measured by miles, we shall find that the heat which otherwise would escape into inter-planetary space, would in a large measure be used up in performing work—namely, in heating and expanding the sinking crust and sediments.

So slowly does the internal heat escape by conduction through the present crust of the globe, that the blanketing of sediment such as we assume, will not affect the temperature of the lower layers of under-crust till long after the compression induced by expansion in the upper layer of rock, and in the sediments themselves, have commenced the work of mountain upheaval.

We thus have a reservoir of power to work upon; a potential force, in fact, to carry on the work initiated by sedimentation, for we must not lose sight of the fact that the lateral compression will be accompanied by a further development of heat where the rocks move upon one another, or are distorted or crushed in the way

that happens in the axis of a mountain range. I have hitherto not attempted to estimate this local development of heat, or even mentioned it as a factor in mountain building, though it has been in my mind all along. It will at all events, whatever be its quantity, by checking the cooling of the under-crust, contribute towards the continuance of the work of mountain building. But the mountain upheaval ended, the work on my theory does not cease; on the contrary it goes on, but in the opposite direction. Decrease of bulk by cooling of the underlayers initiates normal faults, and, as I have already pointed out, normal faults are as great a fact as mountain chains.

The throws of the unequally settling strata are in some cases to be measured by thousands of feet. This is geological work performed in an opposite direction to mountain building and in pretty nearly the same proportion. I have shown* that the expansion of a local area of the earth's crust, by heat, will give a vertical elevation of three times the linear vertical expansion, and the same reasoning applies to subsidence through contraction by loss of heat. Whatever lessens the bulk of the solid under-crust will produce subsidence in that above it, for the pressure at the depth of a few miles is so great that the contraction would be followed up by a movement of the surrounding matter. It must not be lost sight of, that the *weight* of the mass increases as the *cube*, while the *strength* only increases as the *square*.

This it is that fixes a limit to the size of all engineering works, and in the same way the limit of stability is reached, in the case of the earth's crust, very rapidly. The cooling of a section of the earth's crust 500 × 500 × 20 miles, 1,000°F would lessen its volume by about 50,000

* "Origin of Mountain Ranges," pp. 113-4.

cubic miles. To meet such a contraction re-adjustments by faulting would be required to an enormous extent, and the most rigid materials of which the earth is composed would give way as readily as moistened sand in a laboratory experiment.

It would be an interesting calculation to estimate over a selected area the amount of increase of bulk represented by elevatory movements, and of decrease as represented by faulting. My view is, that could this be done with accuracy they would be found to be pretty nearly the same. In this connection it must ever be borne in mind that the decrease in volume takes place in an increasing ratio downwards till the zone of greatest contraction is reached, which will vary no doubt proportionately to the previous effects of mountain building or upheaval.

This is the very thing that is wanted for the fitting together or closing up of the fissures in the rigid strata nearer the surface. It creates a void to be filled by the gravitation of the mass above, doubtless by repeated small movements rather than by huge catastrophes. The formation of such an enormous fault as that of Craven and its continuation bounding the Vale of Eden, must cover an enormous length of time. I am no believer in sudden changes and universal catastrophes. I have shown that all the dynamical theories of the earth ultimately hinge upon changes of temperature. Now changes of temperature by the very necessity of the laws of conduction in solid masses must take place very slowly. On the other hand, the effects cannot accumulate beyond the limits fixed by the strength of the materials of which the earth is composed.

To those catastrophists who suppose that strains accumulate on the earth sufficient to produce a moun-

tain at one up-lift, or a large fault at one down-throw, it seems only necessary to point to what takes place in mines, where the removal of the strata at depths of half a mile are still felt by subsidences at the surface. In these cases the areas of removed rock, to the depth of the covering rock, are small as compared to the areas and depths affected by the operations of Nature. The nature of the materials of the under-layers, and the mode in, and amounts to, which they contract, doubtless determine the nature and direction of the faulting in different districts. These adjustments, we have every reason to believe, looking at the question from a dynamical point of view, must take place many times before the final stage of rest is reached. Every time such an adjustment takes place the blocks of strata will be affected in a somewhat different manner. If we appeal to Nature we find that this is exactly what has happened. Slickensides, with which we commenced our investigations, point clearly in this direction, for it is difficult to find striæ in the same quarry having an exact parallelism of direction. We thus have the undoubted satisfaction of seeing that mechanical theory and observation agree, which is not always the case, certainly from no fault of mechanics, but because those who apply mechanical principles are often insufficiently acquainted with the structure of the earth, if indeed they are not almost entirely ignorant of it. Dynamical geological questions are not to be settled by dogmatic physicists innocent of geological knowledge, but who, unfortunately, are often eagerly listened to by a confiding public. The study of physics and geology should go hand in hand, for I believe it is in that direction that the most fruitful discoveries will, in the future, be made. Let us hope that the Liverpool Geological Society will do its best to aid so desirable an object.

APPENDIX.

DESCRIPTION OF SPECIMENS.

By Dr. J. Shearson Hyland.

SPECIMEN No. 5.—*Lower Bunter Sandstone, Bank Hey Delf, Lancashire.*

The quartz is mostly rounded, but is also at times angular. There has been some granulation of this mineral, whereby many of the grains have become split up into several pieces, the pieces no longer being in optical continuity with each other. The quartz encloses thin patches of a yellowish-brown mineral, which is strongly pleochroic. The colors are yellow, yellowish-brown, and greyish-blue; the mineral is probably tourmaline. Liquid enclosures possessing a di-hexaedral form are not infrequent; such are the so-called "negative crystals." These enclosures mostly possess a bubble, which pulsates like a living organism. Enclosures of liquid carbonic dioxide were not to be noticed; they are, however, possibly present, as the quartzes are certainly the so-called old quartzes."

Enclosures containing water are very common, and several grains appear to swarm with them, hence appearing full of minute dusty matter. As binding material silica may have served, but the edges of the several grains are so obscured with hydrate of iron that this cannot be ascertained with any degree of certainty. There are a few grains of felspar in the sandstone, but these are very rare.

SPECIMEN No. 3.—*Keuper Building Stone, Guest's Quarry, Runcorn, Cheshire.*

Angular quartzes are here more frequent. White mica or muscovite is present in thin threads; the dark mica, biotite, is further not wanting. The quartzes are at times very rich in the well-known, hair-like, brown crystals so common in the quartzes of the granites and allied rocks. *Hawes** first ascribed them to a known mineral, considering them, as the result of his observations, to be a titanium mineral, viz., rutile; but, as the writer† has shown, they are at times flakes of hematite, the edges of which are only seen. Liquid enclosures are not so common in the quartzes of this sandstone. Felspar is further very rare.

Although hydrate of iron obscures the outlines of the quartzes, still it is probable that very little cement is present in this rock.

---

* "Mineralogy and Lithology of New Hampshire." Concord, 1878, p. 45.

† Hyland, Tschermak's Mag., 1888, x. 3, p. 218.

SPECIMEN No. 4.—*Pebble Bed Sandstone (Bunter), Pex Hill Quarry, Lancashire.*

The quartz contains here very large liquid enclosures; the constituents are the same as in No. 3.

SPECIMEN No. 2.—*Keuper Sandstone overlying Building Stone, Guest's Quarry, Runcorn, Cheshire.*

Quartzes very much rounded, and very much coated with hydrate of iron. The rock appears to be very friable.

SPECIMEN No. 4 (1*h*).—*Slickenside in Triassic Sandstone, Cheshire (Keuper ?) Cut parallel to plane of Slickenside.*

This is a very compact sandstone, and the grains of quartz are firmly embedded in a ground mass which consists of small splinters of quartz and a little amorphous silica. Undulose extinction is not so frequent as one might expect from the pressure that has evidently been brought to bear upon the rock. Liquid enclosures with movable bubbles are often to be seen, but what is specially remarkable are the tufts of tourmaline one finds embedded in the quartzes. Felspar is present, but is, as usual, of rare occurrence.

SPECIMEN No. 3 (1*m*).—*Slickenside on Upper Soft Red Bunter, West Kirby, Cheshire. Cut parallel to the Slickenside plane.*

There seems to have been a considerable granulation of the quartz grains, a result one expects in a slickenside. This slide resembles the preceding one. Zircon occurs as enclosure in quartz.

SPECIMEN 2*b*.—*Slickenside in Slate Rock, Morben Quarry, Machynlleth, N. Wales, cut at right angles to dip plane of Slickenside and parallel with striæ.*

I think the white band has been different originally from the darker in texture. The only mineral change I am able to discover, is the development of a dark mica near the junction of the two bands; this dark mica lies parallel to the plane of schistosity. It is also found developed along the grains, around which the dark streaks sweep. This mica is secondary, and has been formed out of the original clastic material. *Lehmann* (Die Enstehung der altkryst. Schiefergesteine, p. 248) has shown that this mica is always formed along planes of movement. Between the light and black bands there is still a lighter band in which both felspar and quartz are to be noticed. This light band is free from the rutile-needles to be shortly described. There is no trace of mica in the dark band. The grains around which the mica has formed in the light band cannot be ascribed definitely to either quartz or felspar as they have been altered, and hence give no clear interference figure in con-

vergent light. Some of them appear however to be felspar, and have a thin covering of a greenish indefinite substance which has been termed Viridite.

The dark matter in this slide, both in light and dark bands, as also in Slide 2a (cut parallel with plane of Slickenside) resolves itself under high powers into those needles so highly characteristic of slates, and which were first described by *Zirkel*, and found by *Sauer* on analysis to be rutile (Ger Thonschiefer-Nädelchen). They are very minute, hair-like in character, and appear to form in these specimens no small part of the rock. I have never in my experience met with an instance where they are so plentiful as in these slates. They are also present in heart-shaped twins. Tourmaline and zircon are also to be observed, but are very subordinate to rutile in quantity.

SPECIMEN 4a.—*Cut parallel with the plane of Slickenside. (Slickenside in Middle Slate Quarry, Llansaintfraid Glyn Ceriog, North Wales.*

There is here much evidence of great change having occurred; the quartzes have been broken up into smaller grains no longer in optical continuity with each other, in short granulation has resulted in the formation of a quartz-mosaic. Calcite is plentiful, and at times shows twin-lamellae, probably secondary owing to movement. Rutile needles cannot be found, and the black matter is probably, to some extent, carbonaceous. There are decided evidences of movement present.

4b.—*Slide from same specimen. Cut at right angles to Slickenside plane and striæ.*

The light band consists largely of calcite, but quartz granules are also frequent. The veins which pierce the black mass are formed of quartz granules. Considerable movement has occurred here. The folds appear very contorted.

SPECIMEN 3b & 3a.—*Slickenside on bedding plane of Sandstone, Deganway, North Wales.*

3a.—*Cut parallel with the plane of Slickenside.*

3b.—*Cut at right angles to Slickenside plane and striæ.*

There certainly appears to have been little modification here. A few of the quartzes and the felspars are granulated. A few broken felspars show that molecular tension is prevalent, and possess undulose extinction.

SOME FAULTS EXPOSED IN SHAFTS AND BORINGS IN THE COUNTRY AROUND LIVERPOOL.

By G. H. Morton, F.G.S.

The country between Huyton and Broad Green, and for two or three miles to the north and the south of the railway, has been long familiar to geologists; but there has always been an uncertainty as to the sub-divisions of the Bunter formation beneath the boulder clay, which covers much of the surface. Since 1854, when the district was surveyed by Prof. E. Hull, F.R.S., down to recent years, there has been great doubt as to whether the Lower Soft Sandstone or the Upper Soft Sandstone occurred over a considerable portion of the country; while the position of the boundary faults between the Coal-measures and the Bunter could not be traced beyond very restricted limits. The line of the great fault between those formations on the east of Huyton has been determined, and its exact position proved in or about 1854, after sinking a shaft 90 yards down to the Tenlands coal. Coal was obtained, but the seam was so crushed that its continuity was frequently obscured, and the undertaking finally abandoned after the loss of a considerable capital. The section gives an idea of the character of the fault, and shows how the coals were dragged down to the west. The shaft was 500 feet from the east of the fault, and the Lower Soft Sandstone is now exposed within 1000 feet on the west of the fault.

In 1856 I described the strata about Huyton Village as being the Lower Soft Sandstone, and in 1863 the

yellow sandstone upon which the church is built. Similar strata exposed in a quarry opposite the "Blue Bell" Inn, on the Prescot road, were stated to belong to that sub-division of the Bunter formation. More recently the yellow sandstone exposed at New Pale, Whitefield Lane, and the red sandstone at Dacre's Bridge, have been described as Lower Soft Sandstone.

In 1876 I had occasion to examine a boring a few hundred feet from Netherlee Bridge, and to report on the probability of finding coal in the neighbourhood of Lee Hall. My report only recommended boring as a forlorn hope, for reaching the Coal-measures did not seem probable as the Upper Soft Sandstone occurred at the surface, according to the Geological Survey Map, and at that time there seemed no reason for doubting its correctness. Although the beds at the bottom of the bore-hole presented some indication of a change, the boring was not resumed, but the quantity of water that issued from it was so great that the land was purchased by the Widnes Local Board and a Pumping Station erected there.

In 1879 I had unusual facilities for examining the district during a Local Government Board inquiry in connection with the water supply of Widnes and St. Helens. Over a considerable portion of the country between the Pebble-beds of the Bunter and the Coal-measures the coarse structure of the soft red sandstone, frequently containing comparatively large rounded grains of quartz, sometimes about the size of hay seeds, $\frac{1}{36}$ to $\frac{1}{35}$ of an inch in diameter, attracted my attention, and I began to doubt whether much of the strata really belonged to the highest sub-division of the Bunter formation. If, however, the strata in question were Lower Soft Sandstone, it seemed improbable that they

could be so thick as had been proved in several borings in wells in the district. Both the bore-holes at Belle Vale and Netherlee were nearly 600 feet deep, and it seemed probable that had the strata all belonged to the lower sub-division, the Coal-measures would have been reached, but as they had not been reached it appeared more probable that the strata belonged to the Upper Soft Sandstone. Prof. Hull and Mr. de Rance both adopted this view, although I had advanced the peculiar structure of the sandstone as evidence in favour of the strata being Lower Soft Sandstone.

In 1883 a boring was made near Hunt's Cross, where below a thickness of 137 feet of boulder clay a red marl was penetrated to the depth of 200 feet, when it was given up, the object having been to obtain water. The marl, it was suggested, might be Permian, or possibly Keuper, but the former was obviously the most probable.

About 1878, and again in 1882, I had occasion to examine the Coal-measure area at Croxteth, originally described by Prof. Hull, but could not add anything to his description or to the section he gave across it. The fault between the Coal-measures and the Bunter on the south-west is evidently in the direction shown on the Geological Survey Map, and there are indications of its course just west of Roby, and that it runs further south in the direction of Halewood. The area in that direction is, however, so deeply covered with boulder clay that the fault cannot be traced on the surface.

About ten years ago a boring for coal was made two or three hundred yards to the west of Naylor's Bridge, Gateacre, over a mile from the previous one at Netherlee Bridge. No Coal-measures were found, but a large quantity of water flowed out from the bore-hole. Influenced by this, the Liverpool Corporation, having failed

to arrange for a site at Belle Vale, made a boring for a temporary supply of water in 1887-8 at Naylor's Bridge; the result is of considerable geological interest, and the details were given by Mr. A. Timmins, C.E., at a recent meeting of this Society. I suppose the Upper Soft Sandstone was assumed to be at the surface, as shown on the Geological Survey Map, and that the depth of water bearing strata was unlimited for all practical purposes, and the base of the Bunter not likely to be reached at a less depth than 1,500 feet, and probably nearer 1,800 feet. Only a shallow shaft was sunk, but a boring was continued to the depth of 440·6 feet. A few pebbles were found at 433 feet, and just below a red marl at 434 feet, sandstone at 435 feet, and just below a purple shale with a glazed fracture resembling the Upper Coal-measures, when the operations were suspended in consequence of an unusual fall of rain on the Rivington watershed having for a time rendered unnecessary a further supply from the sandstone. Mr. J. Parry, C.E., very kindly allowed me to examine the sand, and some pieces of the sandstone and marl from the bore-hole on several occasions, but all the stuff had been so broken up and washed that the finer particles of the sandstone were removed. The lower portion of the sandstone resembled that of the Pebble-beds, and this opinion of mine was confirmed by Mr. Timmins in his recent paper, but our President, Mr. H. Beasley, considered it to be the Lower Soft Sandstone.

After I had examined the sand from the boring, I went to Naylor's Bridge, and unexpectedly found a large quantity of sandstone on the surface that had been thrown out of the excavation made for the Pumping Station. It more closely resembled the Upper Soft Sandstone than the Lower Soft Sandstone, and I concluded that the strata

lower down in the bore-hole belonged to the Upper Pebble-beds, and that the lower beds of the Upper Soft Sandstone were at the surface. In the country around Gateacre all the Pebble-beds belong to the lower part of the sub-division; but the only difference between the Lower and Upper Pebble-beds is that the former contain numerous pebbles and seams of shale, while the latter contains few, if any, of either. The separation of the Pebble-beds into two sub-divisions renders it possible to determine the presence and position of faults previously impossible; but if it will prove of any value beyond the limits of the country around Liverpool and Wirral is very uncertain.

Relying on the regular sequence of the sub-divisions of the Trias, and that the Lower Pebble-beds are so well developed to the west, north, and south of Gateacre, it does not seem possible that the Upper Pebble-beds rest on the Coal-measures. Considering, also, that the Naylor's Bridge boring is on the line of the Croxteth fault, I have come to the conclusion that the boring passed through the base of the Upper Soft Sandstone, gradually entered the Upper Pebble-beds, and at the depth of about 426 feet from the surface reached the boundary fault, and crossed it into the Coal-measures on the eastern or upthrow side of it. A few small quartz pebbles, found at the depth of 433 feet, seem to have been in the fault, and derived from the denuded Lower Pebble-beds which formerly existed on the upthrow side.

It is with some confidence that I submit this explanation of the result of this important boring, and all the observations that have been made tend to confirm it. The Belle Vale boring in the Upper Soft Sandstone has no bearing on the case, and the Netherlee boring, being nearly a mile to the east in the direction of the dip of the strata, may be left out of consideration, though probably

in the Lower Soft Sandstone. The boring for coal on the east of Naylor's Bridge is further from the supposed fault, where it must be very much deeper. Mr. Timmins referred to the Croxteth fault, which he thought brought up the Coal-measures; but his section contained another fault throwing them down again, and it represented the Pebble-beds as resting on the Coal-measures along the intermediate ground in which he supposed the Naylor's Bridge bore-hole to be situated. I am inclined to think that the boring at Hunt's Cross is on the line of the same great dislocation, and to suspect that the apparent thickness of the marl is in consequence of the confusion into which the beds have been thrown.

The microscopic character of the supposed Upper Soft Sandstone from the excavation at the surface at Naylor's Bridge, presented the usual structure—being composed of fine grains of quartz in a matrix of very minute fragments of that mineral, associated with a large proportion of kaolin. The rock was very soft and crumbled rapidly away.

The sand and sandstone from the bore-hole had been so broken up and washed that it was not in a condition to examine with satisfaction. That down to half the depth of the bore-hole resembled the Upper Soft Sandstone at the surface, and was of a decided red shade of colour. Below that depth it became brown, like the ordinary sandstone of the Pebble-beds, and I found a few secondary crystalline grains of quartz at the depths of 276, 282, 286, 349, and 353 feet, supporting the conclusion that the beds at the bottom of the bore-hole belong to quite the top of the Upper Pebble-beds. None of the sand or sandstone, either from the excavation or from the bore-hole, presented the coarseness of grain so common in the Lower Soft Sandstone, and no "hay-

seed" like grains of $\frac{1}{25}$ to $\frac{1}{35}$ of an inch in diameter were found, which could have hardly occurred if the sandstone belonged to that sub-division. Except in one or two localities these large grains have only been found in the Lower Soft Sandstone in the country around Liverpool. Mr. A. Strahan, F.G.S., and Mr. T. Mellard Reade, F.G.S., state that they found them in the Upper Soft Sandstone at Runcorn, and Mr. A. Timmins, C.E., found them in the same sub-division at Stockport; but these places are quite outside this district. Large grains approaching the typical size, in a fine grained matrix, occur under Crown Street, and form the whole of some beds of the Upper Soft Sandstone at Flaybrick, but they are under the required diameter.

In final confirmation of this explanation of the Naylor Bridge boring I obtained from Mr. Parry fragments of a *slickenside* on sandstone from the depth of 426 feet, near the bottom of the bore-hole. The specimens are certainly from a fault, and the rock has a Coal-measure aspect, while the striæ are very clear and distinct.

There are many local examples in which the Wells and bore-holes connected with Water-works cross faults and suddenly reach the Coal-measures or lower subdivisions of the Bunter or Keuper. Reference to a few of those of which I have sections will tend to show how probable the explanation I have given is, compared to the assumption that the Naylor Bridge boring passed through the Lower Soft Sandstone into the Coal-measures.

Whiston Well.—The Well and boring at the Whiston Pumping Station, belonging to the St. Helens Corporation, present an instance of the boundary fault between the Lower Soft Sandstone and the Coal-measures being

penetrated. The Well was sunk 200 yards to the east of the fault, but a boring from the bottom reached it at the depth of 312 feet from the surface, when it was discontinued. An auxiliary well was then sunk about 200 yards still further to the east, and another boring made to the depth of 465 feet from the surface, when a bed of clay was reached, and it was not considered advisable to go deeper. The hade of the fault was found to be double what was expected, and very few instances of such a great slope (26°) have been recorded.

Green Lane Well.—This Well belongs to the Liverpool Corporation, and has for many years yielded an extraordinary large supply of water. A fault has been supposed to occur on the east and the bore-hole to have penetrated it, but recent observations prove that the fault is on the west side of the Well, and that it hades to the west, away from the bore-hole. Numerous parallel slips and joints on the east of the fault probably allow the free passage of water through them, and this accounts for the large supply obtained from the Well.

Borough Road Well — belongs to the Birkenhead Corporation, and a considerable fault between the Upper Soft Sandstone and the Lower Pebble-beds, was intersected by the bore-holes at the depth of 342 feet from the surface.

Flaybrick Well.—The underground works connected with this Pumping Station belonging to the Birkenhead Corporation have crossed two faults, which let down the Keuper into a trough or long narrow area of subsidence between them. Both of the faults run north and south, and may be traced over the surface to the quarries at Flaybrick Hill. Although the area about the well is Keuper Sandstone, it may be seen faulted on both the east and west against the Upper Soft Sandstone of the

Bunter in the heading 200 feet below the surface. It is remarkable that this underground section has proved the thickness of the Keuper Sandstone to be nearly 200 feet, far exceeding that of any other exposed section in Wirral.

Faults of less importance are exposed in the Grange Hill Well at West Kirby, and in others around Liverpool, so that if it should be hereafter proved that the Croxteth fault continues and traverses the country on the east of Gateacre it is only what seems probable, though some further confirmation of its presence there is necessary before it can be finally accepted.

AN EXAMINATION OF SOME VOLCANIC ROCKS OF THE ISLE OF MAN.

By E. Dickson, F.G.S., and P. Holland, F.C.S., F.I.C.

The rocks which have been examined were obtained during the visit of the Society to the island in May, 1888.

As is well known, the greater part of the island, (about four-fifths) is made up of shales and flags, which are supposed to be of Silurian or Cambrian age.

On the east of Castletown Bay and West of Langness Promontory, are patches of a coarse brecciated conglomerate, formerly (and by Cumming in his work on the Geology of the Island) assigned to the Old Red Sandstone, but now regarded as basement beds of the Carboniferous. The same beds occur on the coast for about two miles north of Peel, though here the character of the beds is

entirely different, consisting of a red sandstone rock, conglomerate being absent.

In the south of the island at Castletown, is found a patch of rocks of the Carboniferous limestone series, which are well seen on the coast around Castletown Bay as far as the Stack of Scarlett, and again from Poolvash to Strandhall.

The shore for about two miles from the Stack of Scarlett to Poolvash is occupied by interbedded volcanic rocks; while intrusive rocks are represented by dykes of felstone or elvanite traversing the shales and flags, basaltic dykes traversing all the stratified rocks and cutting through the ash and volcanic agglomerate beds between Scarlett Stack and Strandhall.

It is the volcanic rocks composing these dykes that have been more particularly examined.

There are several points of general interest connected with them:—

First, the felsitic dykes traverse the shales and flags, but not the more recent formations.

Secondly, the basaltic dykes, which are confined to the more southern parts of the Island, traverse *all* the formations, including the volcanic agglomerate and ash between Scarlett Stack and Poolvash.

Thirdly, that while traversing the limestone and schist the basaltic dykes are unbranched, but that when traversing the conglomerate on the west of the Langness peninsula the dykes are branched.

The presence of limestone fossils in the ash between Poolvash and the Stack of Scarlett has been brought forward as evidence that the interbedded volcanic rocks are of Carboniferous age, and that the source was situate

near the sea; but it is possible, and perhaps more probable, that this bed may be composed of material derived from eruptive masses by the ordinary methods of denudation. Cumming supposed that the dykes were of similar age to the interbedded volcanic rocks; Horne, however, in his paper on the Geology of the Isle of Man, (Trans. Edinburgh Geol. Soc., vol. II., 1874) thinks that they belong to the "great series of basaltic dykes in "the south of Scotland and north of England which Prof. "Geikie has proved to be of Miocene Age"; and probably this is the correct view to take. The point is of course one of great difficulty and requiring much more careful investigation. A detailed examination of the rocks themselves will probably throw considerable light on this vexed question.

The directions of a large number of dykes have been taken. Nearly all run in an east and west, or north-east and south-west direction.

The effect of the dykes on the rocks through which they pass is very marked.

Specimens from Crosby Quarry near St. John's (where a dyke of felsite or elvanite runs through the Slate), at the point of junction, have been examined chemically and microscopically. We have also had the advantage of Mr. Rutley's opinions on the various rocks which have been examined, and append his descriptions. A section was made at the point of junction of the two rocks. The following are Mr. Rutley's remarks upon it:

"I. (8) Junction of Elvanite and Silurian.

"The section presents the usual appearance of such "contacts, the line of demarcation between the two rocks "being sharply defined and shewing no evidence of "contact metamorphism.

"The Elvanite consists of fine grained micro-
"crystalline felsitic matter with tolerably numerous "porphyritic crystals of quartz, muscovite, magnesian "mica, orthoclase, and triclinic felspar, possibly oligo-"clase, but their sections do not give trustworthy extinc-"tion angles. In places, the ground mass shews some "staining from hydrated ferric oxide and numerous "opaque yellowish-white specks, which in some cases "may be leucoxene, in others kaolin. Although some of "the brown mica rather closely resembles hornblende, "there is not much evidence of the presence of that "mineral, if any. Very minute crystals apparently of "apatite, are visible but owing to their small dimensions "and their frequent inclusion in other minerals, their "optical character cannot be determined with certainty.

"The foliation of the Silurian rock is well marked. "It may be regarded as a micaceous schist. The mica "is of a dark brown colour, and the crystals frequently "lie with their longer diameters approximately at right "angles to the foliation."

Two chemical analyses have also been made of the same specimen, one of the Elvanite portion, the other of the Slaty or Silurian portion.

Analysis of Elvanite portion of same specimen, Sp. Grav. 2·72:—

SiO_2	74·39
Al_2O_3	15·55
Fe_2O_3	1.35
MnO	0·22
CaO	0·48
MgO	0·33
K_2O	2·14
Na_2O	3·79
Combined Water	1·18
	99·43

Analysis of the slaty portion of the rock at the point of junction:—

SiO_2	49·03
Al_2O_3	24·83
Fe_2O_3	3·68
FeO	5·57
MnO	0·26
TiO_2	1·09
CaO	1·80
MgO	2·68
K_2O	5·09
Na_2O	2·96
Combined Water	2·57
	99·56

Not enough of the specimen remained to enable a satisfactory estimation of the carbonaceous matter to be made. P_2O_5 was detected in this specimen, but was not estimated, as also S.

Thinking it would be interesting to have a specimen of the unaltered slate rock examined chemically so as to compare it with the rock near the point of junction, a specimen was kindly sent by Dr. Tellet, of Ramsey, from Sulby, a place about 5 miles from Crosby.

Analysis of Unaltered Silurian from near Sulby, Sp. Grav. 2·79:—

SiO_2	57·25
Al_2O_3	21·51
Fe_2O_3	1·30
FeO	5·71
MnO	0·48
TiO_2	0·94
CaO	0·61
MgO	1·92
P_2O_5	0·13
S	0·22
K_2O	3·75
Na_2O	1·32
Combined Water	4·32
	99·46

Carbonaceous matter approximately 0·5 per cent.

It seems remarkable that there should be 8 per cent. more silica in the unaltered than in the altered rock.

II. (7). Specimen from the summit of Scarlett Stack.

"An altered basalt: The constituents are—labra-"dorite, serpentine, calcite, chalcedony, leucoxene, and "possibly a small quantity of kaolin. There is a con-"siderable amount of chalcedony present, and this, "together with the serpentine and calcite occurs in "pseudomorphs after olivine. The leucoxene is an "alteration product after ilmenite and apparently some "titaniferous magnetite; one or two of the patches of "serpentine and calcite may be the infilling of vesicles."

Sp. Grav. 2·62. Chemical analysis of the same rock:—

SiO_2	46·70
Al_2O_3	13·74
Fe_2O_3	5·43
FeO	9·86
MnO	a trace.
TiO_2	1·94
CaO	3·95
MgO	6·24
K_2O	1·36
Na_2O...	3·48
CO_2	1·63
Combined Water	5·88
	100·26

III. (12). Specimen of gabbro from the most westerly quarry at Rockmount.

This rock, about the exact character of which there seems to be some little doubt, may be described as follows:—

"The constituents are labradorite, serpentine pseu-"domorphous after olivine and possibly, in some cases,

"after pyroxene, ilmenite, magnetite, and some calcite. "That the felspar is labradorite is shewn by the constant "occurrence of sections giving an oblique extinction "angle of 16°, while others (basal sections) give angles "of about 5°. There are, however, a few crystals present "which afford extinction angles suggestive of a felspar "intermediate between labradorite and bytownite. The "ilmenite is to some extent altered into leucoxene." Sp. Grav. 2·26.

The following is a chemical analysis of the same rock:—

SiO_2	47·13
Al_2O_3	8·48
Fe_2O_3	6·15
FeO	5·54
MnO	0.64
TiO_2	0·58
CaO	11·34
MgO	13·61
K_2O	0 22
Na_2O	1·28
CO_2	0·47
P_2O_5	0·32
Combined Water	3·90
	99·66

IV. (10). Specimen from Dyke near Langness Lighthouse.

"Judging from the extinction angles, some of the "felspars are anorthite, while others may probably be "referred to bytownite. Porphyritic crystals of olivine "are present. These are in great part altered into "serpentine and limonite. The rock is apparently a "much altered anorthite basalt or troctolite."

V. (4). Specimen of Dyke leading from Scarlett Stack to mainland.

"A rock of fine texture, either a basalt or a rock "occupying a position between basalt and andesite. "The constituents of the rock are labradorite, rhombic "pyroxene, magnetite, ilmenite, and secondary products, "viz., leucoxene, pyrites, calcite, and serpentine. The "three latter minerals occur in small quantity, the "pyrites being associated with ilmenite, and the calcite "being apparently pseudomorphous after olivine. A "very little serpentine is associated with the calcite in "these pseudomorphs, and the remainder may have "partly resulted from the alteration of the pyroxenic "constituents."

VI. (2). Specimen from Dyke passing through limestone east of Scarlett Stack.

"A finely crystalline anorthite basalt or troctolite. "The constituents are olivine, in many cases more or "less completely altered into serpentine, anorthite, "ilmenite, magnetite, and some minute specks of "pyrites."

VII. (8) Specimen of Dyke passing through limestone at Strand Hall.

"The constituents are anorthite, a considerable "quantity of opaque dark brownish matter apparently "limonite, large irregularly-shaped patches of an "isotropic mineral (analcime?) and a little pyrites. "The rock is probably an altered basalt."

VIII. (11) Specimen from Dyke at junction of Dyke with Carboniferous Limestone near Poolvash.

"The Dyke is apparently an anorthite basalt, but "appears very opaque in the section. This is probably "due to its being the very margin of the Dyke, where a "tachylitic condition might be expected. It contains "some well developed porphyritic crystals of augite,

" more or less altered and with a diallage-like cleavage. " There are also numerous small lath-shaped crystals " of anorthite."

IX. (5) Specimen of Limestone at junction with Dyke.

" There is a very considerable amount of opaque, " black (probably carbonaceous) matter present in this " section, and there are indistinct traces of small fossil " organisms, some of which may be sections of the " ossicles of minute crinoid stems."

X. (9.) Specimen from Dyke of Felsite or Elvanite in junction with shale or slate (Crosby Quarry).

" This appears to be a quartz felsite of the ordinary " type. It contains a certain amount of limonite, and " it is possible that a little of the opaque black matter " present may be carbonaceous material derived from " the shale."

MEMBERS

OF THE

LIVERPOOL GEOLOGICAL SOCIETY.

HONORARY MEMBERS.

WILLIAM BRYHAM, Wigan.

CHAS. CALLAWAY, D.Sc., F.G.S., Wellington, Salop.

ARCHIBALD GEIKIE, D.Sc., F.R.S., London.

HENRY HICKS, F.G.S., M.R.C.S.E., London.

JOHN W. JUDD, F.R.S., F.G.S., London.

*DANIEL MACINTOSH, F.G.S., 32, Glover Street, Birkenhead.

WILLIAM PENGELLY, F.R.S., F.G.S., Torquay.

SIR A. C. RAMSAY, F.R.S., F.G.S., London.

FOREIGN CORRESPONDING MEMBERS.

M. A. DAUBRÉE, Museum of Natural History, Paris.

DR. A. HEIM, University of Zurich.

MAJOR-GEN. N. VON KOKSCHAROW, Inst. of Mines, St. Petersburg.

PROF. J. VILANOVA-Y-PIERA, University of Madrid.

DR. A. F. RENARD, Museum of Natural History, Brussels.

BARON F. VON RICHTHOFEN, Berlin.

PROF. J. J. STEVENSON, University of New York.

MEMBERS.

*ARCHER, F., B.A., 14, Cook Street.

*†BEASLEY, H. C., Prince Alfred Road, Wavertree.

*BROWN, J. CAMPBELL, Prof., D.Sc., F.C.S., 27, Abercromby Square

DAVIES, D., 55, Berkley Street.

*DICKSON, E., F.G.S., 30, Eastbourne Road West, Birkdale.

DEANE, W. D. H., M.A., 2, Arundel Avenue, Sefton Park.

*†ESKRIGGE, R. A., F.G.S., The Woodlands, New Brighton.
18, Hackins Hey.

FITZPATRICK, M., 62, Seel Street.

*FITZPATRICK, J. J., 62, Seel Street.

†FOSTER, E., 41, Arundel Avenue, Sefton Park.

GOFFEY, T., Nicholas Road, Blundellsands.

*GRENSTED, Rev. F. F., M.A., Cavendish Road, Blundellsands.

GASKING, Rev. S., B.A., F.G.S., 8, Hawthorn Terrace, Liscard.

GOODALL, W., 43, Walmer Road, Birkdale.

HANCE, E. M., LL.B. (*Hon Treasurer*), Municipal Offices, Dale Street.

*HERDMAN, W. A., Prof., D.Sc., F.R.S.E., University College.

*HIGGINS, Rev. H. H., M.A., 29, Falkner Square.

*HEWITT, W., B.Sc. (*Hon. Secretary*), 16, Clarence Road, Birkenhead.

*HOLLAND, P., F.C.S., 26, Talbot Street, Southport.

JACKSON, G. O., 5, Coltart Road.

*JEFFS, O. W., 12, Queen's Road, Rock Ferry.

KEYTE, T. S., C.E., 9, Chatham Place, Edge Hill.

KNIGHT, A. H., F.C.S., 22, Radnor Place, Claughton.

*LOMAS, J., 23, Avondale Road.

MOORE, C. C., 125, Chester Road, Hartford, Northwich.

*MARRAT, F. P., 21, Kinglake Street.

*MOORE, T. J., C.M.Z.S.L., 14, Gardner Road, West Derby.
Liverpool Museum.

MORTIMER, Captain, Liverpool.

*†MORTON, G. H., F.G.S., F.R.G.S.I., 209, Edge Lane.

NEWALL, E., 14, Elm Grove; Tranmere.

PATERSON, J., C.E., F.G.S., Palmyra Street, Warrington.

PALMER, S. J., M.B., M.R.C.S., Netherfield Hospital.

*†PICTON, Sir J. A., F.S.A., Sandy Knowe, Wavertree.
4 and 5, Queen Buildings, Dale Street.

*POTTER, C., 101, Miles Street.

*†READE, T. M., C.E., F.G.S., Park Corner, Blundellsands.
Canning Chambers, South John Street.

*†RICKETTS, C., M.D., F.G.S., 18, Hamilton Square, Birkenhead.

*†ROBERTS, I., F.G.S., Kennessee, Maghull, Lancashire.
39, Gardner's Row.

RICHARDSON., W. A., C.E., Valley Lodge, Borough Road, Birkenhead.

ROBINSON, J. J., Blundellsands Road, Great Crosby.

SHONE, W., F.G.S., Upton Park, Chester.

*TATE, A. NORMAN, F.I.C., F.C.S., F.G.S., 9, Hackins Hey.

*TATE, G., Ph.D., F.C.S., Liverpool College of Chemistry.
96A, Duke Street.

*TIMMINS, A., C.E., Argyll Villa, Runcorn.

TUNSTALL, J., 45, Vine Street.

*WARD, T., Brookfield House, Northwich, Cheshire.

ASSOCIATES.

MORTON, Miss S. E., 209, Edge Lane, Liverpool, E.

READE, Mrs., Park Corner, Blundellsands.

---

* Have read Papers before the Society.
† Contribute annually to the Printing Fund.

CONTENTS.

PAGE

PROCEEDINGS

OF THE

Liverpool Geological Society.

SESSION THE THIRTY-FIRST,

1889-90.

EDITED BY W. HEWITT, B.SC.

(The Authors, having revised their own Papers, are alone responsible for the facts and opinions expressed in them.)

PART 2. VOL. VI.

LIVERPOOL:
C. TINLING AND CO., PRINTERS, VICTORIA STREET.
1890.

PROCEEDINGS

OF THE

Liverpool Geological Society.

SESSION THE THIRTY-FIRST,

1889-90.

EDITED BY W. HEWITT, B.Sc.

(The Authors, having revised their own Papers, are alone responsible for the facts and opinions expressed in them.)

PART 2. VOL. VI.

LIVERPOOL:

C. TINLING AND CO., PRINTERS, VICTORIA STREET.

1890.

OFFICERS, 1889-90.

President:

CHAS. RICKETTS, M.D., F.G.S.

Vice-President:

E. DICKSON, F.G.S.

Ex-President:

H. C. BEASLEY.

Honorary Treasurer:

EDWARD M. HANCE, LL.B.

Honorary Librarian:

J. J. FITZPATRICK.

Honorary Secretary:

WILLIAM HEWITT, B.Sc.

Council:

T. GOFFEY.
OSMUND W. JEFFS.
J. LOMAS, Assoc.N.S.S.
G. H. MORTON, F.G.S.
T. MELLARD READE, C.E., F.G.S.

LIST OF SOCIETIES, ETC., TO WHICH THE PROCEEDINGS OF THE LIVERPOOL GEOLOGICAL SOCIETY ARE SENT.

(Publications have been received in exchange during the Session from those marked)*

*Academy of Natural Sciences, Philadelphia.
Advocates' Library, Edinburgh.
*Australian Museum, Sydney.
*Belfast Naturalists' Field Club.
*Birkenhead Free Public Library.
* „ Literary and Scientific Society.
Birmingham Philosophical Society.
Bootle Free Public Library.
British Museum.
British Museum (Natural History) Geological Department.
*British Association for the Advancement of Science.
*Bristol Naturalists' Society.
Bodleian Library, Oxford.
*Boston Society of Natural History, U.S.
*Chester Society of Natural Science.
*Colorado Scientific Society.
Dudley and Midland Geological and Scientific Society.
*Essex Naturalists' Field Club.

Editor of "Geological Record."
,, "Nature."
,, "Geological Magazine."
,, "Science Gossip."
Ertborn, Le Baron O. Van, Anvers, Belgique.
Geological Society of Edinburgh.
Geological Society of Glasgow.
*Geological Society of London.
*Geological Society of Manchester.
Geological Society of Norwich.
*Geological Society of Australasia, Melbourne.
*Geological Survey of the United States.
Geological Survey of India.
*Geological Survey of Canada.
Geological Survey of Missouri.
*Geologists' Association, London.
*Glasgow Philosophical Society.
Hungarian Karpathian Society, Locse.
Imperial Academy of Naturalists, Halle, Prussia.
*Kansas Academy of Sciences, Topeka.
*Leeds Philosophical and Literary Society.
Leeds Geological Association.
Liverpool Athenæum.
,, Chemists' Association.
* ,, Free Public Library.
* ,, Geological Association.
* ,, Literary and Philosophical Society.
,, Lyceum Library.
,, Philomathic Society.
* ,, Engineering Society.
* ,, Astronomical Society.
* ,, Science Students' Association.
*L'Universite Royal de Norvége, Christiana.
*Manchester Association of Engineers.
Manchester Literary and Philosophical Society.

Minnesota Academy of Natural Science, Minneapolis, U.S.
Musée Royal d'Histoire Naturelle de Belgique.
Museu Nacional, Rio de Janeiro.
Museum of Practical Geology, Jermyn Street, London.
*North of England Institute of Mining and Mechanical Engineers.
*New York Academy of Sciences.
Owens College, Manchester.
Patent Office Library, 25, Southampton Building, Chancery Lane, London, W.C.
*Royal Dublin Society.
Royal Geological Society of Ireland, Dublin.
Royal Society, London.
*Smithsonian Institution, Washington, U.S.
*Société Geologique de Belgique, Liege.
*Société Geologique du Nord, Lille.
*Société Impériale des Naturalistes de Moscow.
*Société Royale Malacologique de Belgique.
*Sociedade de Geografia de Lisbon.
*Toscana Societa di Scienza Naturali.
*University Library. Cambridge.
University College, Bangor.
" " Liverpool.
*Warwickshire Natural History and Archæological Society.
Watford Natural History Society.
*Wagner Free Institute of Science, Philadelphia.
Woodwardian Museum, Cambridge.
Yorkshire Geological and Polytechnic Society.

PROCEEDINGS

OF THE

LIVERPOOL GEOLOGICAL SOCIETY.

SESSION THIRTY-FIRST.

OCTOBER 8TH, 1889.

THE PRESIDENT, H. C. BEASLEY, ESQ., in the Chair.

Mr. H. ASHTON HILL, C.E., was elected an Ordinary Member.

The Hon. Treasurer submitted his Statement of Accounts.

The Officers and Council for the ensuing year were elected.

The President read his ANNUAL ADDRESS.

NOVEMBER 12TH, 1889.

THE PRESIDENT, DR. C. RICKETTS, F.G.S., in the Chair.

Mr. F. R. CHALMERS, Mr. D. CLAGUE, F.G.S., Mr. L. CUMMING, M.A., Mr. T. H. DAVIS, F.I.C., Mr. I. E. GEORGE, Mr. J. KENNARD, F.R.G.S., Mr. R. C. LINDSAY, B.Sc., Mr. W. H. MILES, Mr. C. E. MILES, Mr. W. SEMMONS, and Mr. J. TWEMLOW, were elected Ordinary Members.

REPORTS on the FIELD MEETING AT BURTON, by Mr. H. C. BEASLEY, and on the FIELD MEETING AT THE BARTON SECTION OF THE SHIP CANAL, by Mr. P. F. KENDALL, F.G.S., were read.

DECEMBER 10TH, 1889.

THE PRESIDENT, DR. C. RICKETTS, F.G.S., in the Chair.

The following papers were read :—

REPORT ON THE EXCURSION OF THE SOCIETY TO THE NORTH COAST OF ANGLESEY.

BY T. MELLARD READE, C.E., F.G.S.

PHOTOGRAPHIC RECORDS OF THE ROCKS.

BY OSMUND W. JEFFS.

JANUARY 14TH, 1890.

THE PRESIDENT, DR. C. RICKETTS, F.G.S., in the Chair.

The following papers were read :—

NOTES ON GLACIAL MORAINES.

BY L. CUMMING, M.A.

NOTE ON A BOULDER MET WITH IN DRIVING A SEWER HEADING IN ADDISON STREET.

BY T. MELLARD READE, C.E., F.G.S.

FEBRUARY 11TH, 1890.

THE PRESIDENT DR. C. RICKETTS, F.G.S., in the Chair.

The following papers were read :—

REMARKS ON THE CONTORTED SCHISTS OF ANGLESEY.

BY C. RICKETTS, M.D., F.G.S.

EXAMINATION OF SEDIMENT FROM THE RIVER ARVEYRON, NEAR ARGENTIÈRE.

By E. DICKSON, F.G.S., and P. HOLLAND, F.C.S.

MARCH 11TH, 1890.

An EXTRAORDINARY MEETING was held to discuss a proposed alteration of the rules. Mr. J. J. FITZPATRICK was voted to the Chair.

At the ORDINARY GENERAL MEETING which followed, Mr. G. H. MORTON, F.G.S., was in the Chair.

The following papers were read:—

NOTES ON A GRANITE BOULDER FROM PEN-Y-BONT, AND A FELSITE BOULDER FROM BEBINGTON.

BY I. E. GEORGE.

NOTES ON A VISIT TO THE CUPRIFEROUS SANDSTONES OF NAVARRE.

BY W. SEMMONS.

APRIL 15TH, 1890.

THE PRESIDENT, DR. C. RICKETTS, F.G.S., in the Chair.

An EXTRAORDINARY MEETING was held, and the following alteration of the rules was resolved upon:—

RULE 23.—To make the last sentence read: "The retiring Council shall suggest a list of Officers for the ensuing session, and the names of two members who are not of their own number, for election at the Annual Meeting, such list being sent out to each member of the Society with the circular calling the Annual Meeting."

RULE 24 to read: "The election of the Council shall take place at the Annual Meeting, in the following order—first the officers, and next the remaining five members of the Council, including two members not on the previous Council. It shall be competent for any member of the Society voting to substitute other names for those suggested by the Council."

At the Ordinary General Meeting,

Mr. J. Dunbar Kelly was elected an Ordinary Member.

The following papers were read:—

RECENT DISCOVERY OF A BONE CAVE AT DEEP DALE, NEAR BUXTON.
By J. J. Fitzpatrick.

NOTE ON THE EXAMINATION OF SOME ANGLESEY ROCKS.
By E. Dickson, F.G.S., and P. Holland, F.C.S.

WHAT BECOMES OF THE WATER EJECTED FROM VOLCANOES?
By H. C. Beasley.

NOTE ON SOME MAMMALIAN BONES FOUND IN THE BLUE CLAY UNDER THE PEAT AND FOREST BED AT THE ALT MOUTH.
By T. Mellard Reade, C.E., F.G.S.

Field Meetings were held during 1889, at—

North Coast of Anglesey.
Barton Section of Ship Canal.
Llangollen.
Burton.
Billinge.
Glazebrook Section of Ship Canal.

PRESIDENT'S ADDRESS.

THE LIFE OF THE ENGLISH TRIAS.

In the address which I had the honour of reading before the Society last year I pointed out how very vague and uncertain were the conclusions as to the conditions prevalent in this country during the Triassic period.

In continuation of the subject of the latter part of that address, I propose this evening to refer to some of the comparatively few organic remains that the Bunter and Keuper rocks have yielded in this country.

The study of organic remains may be considered under two aspects. I. From a biological point of view as illustrating the succession of life upon the earth; whether as a succession of independent creations, as was formerly supposed, and which forms the leading theme of Sir Roderick Murchison's Siluria; or as the gradual evolution of present forms from older ones, as is now generally held. II. It may be considered from the geological point of view, as illustrating the conditions prevailing at each successive period, and so helping us to work out the history of the development of the earth itself and all connected with it.

Regarding organic remains from what I have called the geological point of view, more attention should be paid to their exact position in the series, the character of the matrix, the conditions indicated by the nature of the stratum in which they are found, and its relation to those above and below it, than is often done. The more important finds are very carefully described by

specialists in the particular branch of biology to which they belong, and every minute detail regarding their structure and affinities most accurately recorded; whilst the other particulars to which I have referred are too often slurred over. In some cases the exact locality in which they were found is entirely overlooked or forgotten, and thus their geological importance is greatly lessened or entirely lost.

Mr. Prestwich* states the number of species whose remains have been found in the Trias (not including the Rhætic beds) in this country as 78, of which 35 are foraminifera from the Keuper. Including the Rhætic beds they number 200 species, against 1851 in the Lias above and 229 in the Permian below. The poverty of organic remains is more marked when we remember that the Triassic rocks cover as great a superficial area in England as any other formation except the Cretaceous. Of plants there are only 12 species included in the above; but the plant remains are so very fragmentary that possibly we may have traces of many more that are not at present recognisable. Whilst, however, the Triassic rocks offer little promise to the mere collector of numerically adding to his list, the real worker may rest assured that anything he may find will be of some importance, and one recognisable fossil may throw light on the meaning of many of the undecipherable fragments already found. I have lately endeavoured to get some idea of what organic remains from English Triassic rocks below the Rhætic beds are preserved in our provincial museums, &c. Whilst some of these possess Triassic fossils of inestimable value, the bulk of them consist of footprints, principally from Storeton and

* Geology: Chemical, Physical, and Stratigraphical, vol. 2, pages 156 and 333.

Lymm. But whilst these quarries seem to have yielded the greatest number of examples, priority of discovery must be given to the footprints found in the sandstones of Dumfries, which (preceding the well-known discoveries in Saxony) were described by Dr. Duncan to the Royal Society of Edinburgh in 1828, and are the subject of a most eloquent passage in Buckland's Bridgewater Treatise.*

The footprints with which the quarries in this district have enriched so many collections are familiar to us all, and in the absence of further remains it was easy for the inner consciousness of an imaginative geologist to evolve the monstrosity that adorned the pages of earlier treatises, but which now has gone the way of many other hobgoblins that figured in the teaching of our childhood. Thanks to further discoveries in this country, and the careful study of remains found elsewhere, and in other formations, we can now picture, though somewhat dimly, a Salamandroid Amphibian, gigantic as the *Labyrinthodon Jaegeri*, with its skull measuring 3 feet by 2 feet, or diminutive as its congener *Branchiosaurus salamandroides*, of which I have here, not the original fossil, but a very perfect electrotype of it, measuring about 1 inch by 2, and displaying the almost complete skeleton.

By far the most important finds of the bones of this animal were made in the neighbourhood of Warwick, and are now in the museum there. They consist of rather more than thirty bones that have been identified, and, according to Professor Owen, they belong to four or five different species. They were all found in the lower Keuper, in what I should suppose to represent the

* See Nat. Hist. Museum, S. Kensington, Geological Gallery No. 11.

Keuper building stone of this neighbourhood. Some of these were described by Professor Owen in 1842*, and an account of them may be, perhaps, more conveniently referred to in Owen's Palæontology (1860), pages 184, *et seq*. They again formed the subject of a paper by Mr. J. C. Miall in 1874†, who had also before him the material that had been found in the interval. Accompanying Mr. Miall's paper are some very good figures of many of the bones with their peculiar sculpturing. As is usually the case the fragments of the jaws were most perfect.

I was able a few months ago to visit the quarry at Coten End, Warwick, where a great part of the remains were found. Unfortunately the base of the Keuper is not visible, but it is clear that these beds are near the base, and that they rest upon the Permian marls. They consist of a tolerably compact grey, or cream-coloured sandstone with small nodules of clay, and cavities formerly occupied by the same. There is little current bedding compared with what is usually found in our district. A thickness of about 30 feet was exposed in the section. As the quarries have not been worked for a long time there were no spoil heaps to look through, and for the present there is little hope of the discovery of further remains.

Other and later finds of Labyrinthodont remains have been made in the South of England. In the autumn of 1875 Mr. H. J. Johnston Lavis discovered near Sidmouth a remarkably well-preserved lower jaw and other remains, and in Vol. 32, Part 3, of the Q.J.G.S. will be found two papers which will well repay perusal. The first is by Mr. Lavis, most carefully describing the bed in which

* Trans. Geol. Society. 2nd Series, vol. 6.

†Q. J. G. S., vol. 30, page 417.

they were found, and its position in the Triassic series there; the other by Prof. Seeley, giving an exhaustive description of the remains and their biological bearing. It is not safe on our present knowledge to attempt to accurately correlate the beds on the south coast with those of this district; but it is sufficient to point out that these remains were found about ten feet from the top of the sandstone underlying the marl that there forms the uppermost member of the Triassic series.

In January, 1884, Mr. N. T. Metcalf, F.G.S.,* described further vertebrate remains found by Mr. H. J. Carter, F.R.S., near the same place, viz., High Peake Hill, between Sidmouth and Budleigh Salterton, and gives the following section:—

	Feet.
Supra-Cretaceous Gravel and Green Sand ..	118
Trias, Upper Marls	200
—,,— Upper Sandstones	200

The remains found by Mr. Carter were numerous small fragments scattered through the sandstone, which under the microscope gave evidence of bony structure. He also found sundry fragments apparently belonging to the jaw-bones of Labyrinthodonts. The whole of these remains are, or were, in the Natural History Museum, South Kensington. This locality seems to be one to which we may look for further discoveries in the future, for it was in the lower portion of this sandstone that Mr. Whittaker, F.G.S., discovered the remains of Hyperodapedon in 1868 (Q.J.G.S., vol. 25, pages 146 to 156), and, in the marls above, the plant remains now in the Exeter Museum. A further short paper on the vertebral remains, by Mr. Carter, will be found in Q.J.G.S., vol. 44, page 318.

* Q.J.G.S., vol. 40, page 257.

That the Labyrinthodont animals were not so rare as we might suppose from the paucity of their remains, is, however, amply proved by the numerous examples of their footprints that are met with at different horizons in the Keuper series in many localities. That the very remarkable footprint originally attributed to an unknown animal called the Cheirotheriun really belongs to the Labyrinthodon, could hardly be proved from anything found in England, though it might be assumed; but from its association with its remains on the Continent there is a fair probability that it is so. We must remember, however, that Mr. Miall, as we were reminded by Mr. Morton three years ago, says that "There is not a single distinctive Labyrinthodont feature about the Cheirotheriun." Besides the impressions of its feet, there is what would appear to have been the track of its tail. This is very clearly marked on two or three large slabs at Warwick, where there is a complete set of footprints, and a strongly marked groove in a median line following their direction. Besides these there are some other records of the animal's habits. Mr. Brodie pointed out to me at Warwick an impression on a slab as if the animal had squatted down on its haunches; and I was interested to find a few weeks since two slabs in the Bootle Museum presenting the same appearance, where the impressions—or, rather, casts of the impressions—are more perfectly preserved. They are both in relief. The mud to the rear of the depression was slightly raised and wrinkled. The depression itself bore a distinct impression of the armoured integument of the animal. One slab shews distinctly parts of a limb. At a short distance is another impression of a portion of the integument. Unfortunately the museum authorities have not at present completed their arrangements for

the display of these and numerous other rather bulky fossils that are stowed away in the basement of the building. There seems some doubt whence these slabs were originally obtained, but they were formerly in the Liverpool Royal Institution, and in all probability came from Storeton.

The mystery that seemed to associate itself with these huge footprints has, perhaps, withdrawn some of that attention that might have been most usefully bestowed on those of smaller animals, which often cover almost the whole of the slabs on which the larger footprints have been preserved. Many are like small representatives of the larger ones, others have been referred to the Rhynchosaurus, but there are numerous others which so far have not been deciphered.

Of the remains of the Rhynchosaurus the best have, I believe, been found at Grimshill, where there are extensive quarries in the Lower Keuper, and there is in the museum at Shrewsbury a fine collection of these bones. Other examples from the same place are to be seen in the Natural History Museum, South Kensington.* Rhynchosaurus remains from Grimshill were first described by Owen in 1842, and an account of them may be found in his Palæontology. They were in a fine grained sandstone, and also in a coarse burrstone; they were found associated with the footprints. The Keuper of Grimshill is a fine white sandstone, well exposed in the quarries, which are easily reached from Liverpool. Fossils, where preserved at all, would probably be

*See Reptilian Gallery, Palæontological department, Table case, No. 12, for skull and mandibles of Rhynchosaurus recently developed from the matrix, and showing the dentition. The same case also contains *Hyperodapedon Gordoni* and cast of Telerpeton from Elgin.

tolerably perfect. I have not been fortunate enough myself to find any there, but I have found some of the most perfect examples of rain drops and ripple marks I have seen anywhere. Numerous Rhynchosaurian foot-prints have been found in a quarry at Shrewly, in Warwick, which I shall describe later on, and the Natural History Museum, South Kensington, has some Rhynchosaurian remains from Warwick.

The sandstones of Elgin were for many years the subject of disputation between stratigraphists and palæontologists, for whilst one part of what appeared to be one series yielded the remains of the strange fishes of the "Old Red," another part gave here and there bones of reptiles. However, the fish and reptilian remains were not mixed, and it is now generally admitted that the white sandstones in which *Telerpeton*, *Hyperodapedon*, and *Staganolepis* have been found, are of Triassic age. The former and the latter appear only to have been found at Elgin, but Hyperodapedon remains have been found at Warwick, and are in the Museum there. They have also been found at Sidmouth by Mr. Whittaker at the base of the beds before referred to as yielding the Labyrinthodont jaws, and these are now in the Natural History Museum, South Kensington. These remains besides their geological importance, have great interest for the biologist. Professor Huxley in 1859, read a paper on the Staganolepis, maintaining its reptilian nature and crocodilian affinities, though it had hitherto been supposed to be a fish, and in the same paper he pointed out the occurrence in the same beds of a Lacertian Reptile, *Hyperodapedon Gordoni*.*

* Q.J.G.S., vol. 15, page 490; vol. 25, page 188.

After a lapse of twenty-nine years had brought to light further remains he read in May, 1887,* a most important paper on this reptile and its affinities. Already in 1875 he had read another paper on Staganolepis and the Evolution of the Crocodilia,† in which he shewed that the enlarged knowledge acquired in the meantime confirmed his views of 1859.

Through the kindness of the Rev. Dr. George Gordon I am able to give the present position of most of these fossils. The Elgin Museum contains remains of Staganolepis, and others are in the National Collection, South Kensington.‡ There is no specimen of the Telerpeton, the first found reptile, in the Elgin Museum, but there are remains in the possession of a gentleman in the neighbourhood, and the original specimen is in the hands of Jas. Powrie, Esq., of Reswaller. Of the Hyperodapedon, the fine example referred to by Prof. Huxley in his paper in 1887, is, I believe, in the Natural History Collection, South Kensington, but the earlier specimens are in the Elgin Museum. There are several blocks from the same upper beds in the Elgin Museum containing casts chiefly of undescribed reptiles, as Dr. Gordon remarks, "awaiting the elucidation of the expert." ¶ Other specimens are in the Museum of Science and Art, and of the Geological Survey, Edinburgh. As Prof. Huxley has traced the evolution of the crocodile from a Triassic ancestor, so

* Q.J.G.S., vol. 43, page 675.

† Q.J.G.S., vol. 31, page 423.

‡ The Jermyn Street Museum contains a fine example of *Staganolepis Robertsoni*, a cast of Telerpeton, and two slabs of footprints, all from Elgin.

¶ Remains of Dicynodon are reported to have been found in the Elgin Sandstone; see Professor Judd's letter to "Nature," vol. xxxii, page 573, October, 1885.

he would refer the later Dinosaurs to the Thecodontosaurus, &c., of the Triassic conglomerate at Bristol. It was formerly disputed whether this Dolomitic conglomerate was or was not to be referred to an earlier formation; but it appears to be part of a belt of rock more or less of a conglomerate, bounding the midland Triassic basin on the south-west, and forming the base of the series. What its exact age is is not quite clear, but probably Upper Keuper. At Clifton it lies unconformably on the Carboniferous limestone. The remains were originally described by the discoverers, Messrs. Riley and Stuckbury, in March, 1836, and have since been the subject of several papers by Prof. Huxley. The actual spot where they were found is not now to be seen, the land having been built over; but from the sections given with Mr. Etheridge's paper they appear to have been in a hollow in the surface of the Carboniferous Limestone filled with the Conglomerate. To Mr. Etheridge's paper on the Dolomitic Conglomerate of Bristol I must refer you for a further account; it will be found in the Q.J.G.S., vol. 26, page 174, and is a very exhaustive paper on the subject. Mr. Edward Wilson, F.G.S., to whom I am much indebted for assistance, informs me that the large and important type series of the Thecodontosaurus is in the Bristol Museum, and that a duplicate series has lately been acquired by the Natural History Museum, South Kensington.

I may refer here to the three-toed footprints found in the Dolomitic Conglomerate of Glamorganshire, and described by Mr. W. J. Sollas, F.G.S., who suggests that they may have been made by an animal allied to those whose remains were found in the same formation near Bristol.*

* Q.J.G.S., Vol. 35, page 511.

Fish remains from the Trias are fairly numerous, but are from a limited number of localities—the *Dipteronotus Cyphus* from the Bunter of Bromsgrove, is described and figured by Sir P. M. de Grey Egerton in an early volume of the Proceedings of the Geological Society. It is a little fish of very striking appearance from the small size of its head and a remarkable hump on its back; but its interest to biologists consists in its having such an almost perfectly homocercal tail, as would hardly have been expected so low down in the Mesozoic series. This solitary individual of the species was found by the officers of the "Survey," but I regret that I have been unable to put my hand on the account of its discovery, and cannot say whether its Bunter age is certain.*

One of the most remarkable finds was that of a large shoal of fishes extending for a length of 30 feet in the section at the base of the waterstones, near Nottingham, by Mr. Edward Wilson, F.G.S., of which an account by himself and Mr. E. T. Newton, F.G.S., will be found in the Q.J.G.S., vol. 43, pages 537 to 539, together with figures of the same. Mr. Wilson says: "The fishes "were apparently limited to the lowest stratum of the "waterstones, a bed of greenish yellow sandstone 10 "inches thick, with intercalated streaks of red and green "marl, and a seam of pebbles at the base. The fish "remains were limited to the bottom inch or two of that "stratum." "In addition to the exceptional interest "that is always to be derived from the presence of "organic remains in Triassic rocks, as a rule so barren "of life, there are two points specially noticeable in "connection with the occurrence of these fossils in the

*This very perfect fossil is in the Jermyn St. Museum, and is labelled from the Keuper sandstone.

"Keuper at Nottingham, namely: *first*, the great "number of the fishes, there being quite a shoal of them "for a distance of 30 feet, or thereabout, to the line of "section, the individual fishes even lying over one "another to the middle portion of that distance, but "gradually becoming more widely separated in either "direction until they finally come to an end; and "*secondly*, their occurrence at the junction of the "sub-formations of the Trias." "The basement beds of "the Keuper are a series of gritty false bedded sand- "stones, with fractured quartzite pebbles and strange "wedge-shaped intercalations of red marl and marly "débris irregularly bedded." "The waterstones on the "other hand (at the base of which the fishes occurred, "and to which series they belong) are regularly bedded "fine grained sandstones and marls shewing ripple "marks and sun cracks."

I have trespassed on your time by making a somewhat lengthy quotation from Mr. Wilson's paper, because there we have a minute description of the position in which the remains were found, and of the rocks above and below, which as I said at the commencement of my address was of such importance in Palæontology, regarded geologically, and also because the description of the basement beds tallies so exactly with the same beds in this neighbourhood. The similarity is further shewn when we find Mr. Wilson describing a cast of an Equisetiform plant from the beds immediately above the basement bed. The principal portion of these fishes are in the Museum of University College, Nottingham, but there are also examples in the Bristol Museum, and in the Natural History Museum, South Kensington. Several papers by Mr. J. Shipman, to whom I am much indebted, will be found of great use to anyone studying the Trias of Nottingham.

The fishes as far as could be made out belonged principally to the genus *Semionotus*, but there were other fishes associated with them. In the paper referred to they are carefully discussed, and compared with other Triassic fishes also therein described, and to it is appended a note by the Rev. J. B. Brodie, M.A., F.G.S., on the allied fishes found at Rowington and Shrewly. The quarry at the latter place is by the side of the canal, and is in a rather soft white sandstone with green marly shales above and below it, the whole being overlain by red marls, and underlain again by the same. The section in the quarry as given by Mr. Brodie, in his note above referred to, is as follows:—

	F.	I.
1. Soft Brown-coloured Sandstone, current marked	0	11
2. Green Marls, more or less sandy	4	7
3. Friable Sandstones in beds, divided by Green Marl, softer at the top, and getting harder at the bottom, with Green Marly surface.. ..	7	2
4. Seven or eight beds of Sandstone of variable hardness, with Estheria, divided by Marls, the bottom rock the hardest	5	0
5. Hard Tea Green Marls with Estheria	7	0

In the sandstone have been found *Semionotus Brodiei* (named after the discoverer), but the most numerous fossil remains that have from time to time been found there were remains of Cestracionts, teeth, spines, and occasionally portions of the shagreen. Besides these there are numerous footprints of Labyrinthodon and Rhynchosaurus, and both in the sandstone and the underlying tea-green marl, (a most expressive term) *Estheria minuta*. I paid a short visit to the quarry this summer, and was fortunate in finding the latter in both beds. I should have explained that these Upper Keuper sandstones lie in the midst of the Keuper red marl series, and the red marls above and below are very plainly seen

from the towing path of the canal. The quarry is easily reached from Warwick by way of Hatton Junction Station; leaving the train there, and walking along the canal side for a mile or so brings you to a short tunnel, on the other side of which is the quarry. Following the canal another couple of miles brings you to Rowington, where you have a section of the same rocks, as the canal passes through a cutting 40 feet deep. It is at Rowington that Mr. Brodie found an example of *Palæoniscus superstes.* Examples of these fishes are in Mr. Brodie's private collection and in the Warwick Museum, where also there are some fine specimens of spines and teeth of Acrodus from the neighbourhood. The Natural History Museum at South Kensington also contains examples. The Bath Museum contains a series of fish remains from the Keuper of Ruishton, principally the teeth of *Hybodus, Acrodus,* &c.

Leaving the invertebrata, we come to the most common of all Triassic fossils, the *Estheria minuta,* a phyllopod crustacean that occurs at all horizons in the formation, and has preserved its bivalved carapace intact. In the quarry at Shrewly I was fortunate enough to find them both in the tea-green marls and in the sandstone, in both of which they are plentiful. It is an interesting question as to how it is that this little animal should have left such a plentiful record, when the shells of Mollusca, which are the most plentiful of all fossils in other formations, are only represented by very doubtful examples. We can hardly imagine their non-existence, and Mr. Brodie has in his collection what has every appearance of being the cast of a bivalve from either Rowington or Shrewly.

At the meeting of the British Association in Liverpool, in 1854, Prof. Harkness, F.G.S., exhibited some

markings on the sandstone from Dumfries, which he believed to be the tracks of Crustaceans.

Annelid tracks have been reported from several localities, but the markings on the thin-bedded shales, &c., are so various, that it is wise to abstain from positive statements on this point. There are, however, in the Chester Museum some that can hardly be mistaken, also a boring and cast passing through the bedding, that can, I think, safely be put down to an annelid.

Although, as we have seen, the greater part of the Triassic fossils have been found in the neighbourhood of Warwick, even there the plant remains are too fragmentary for identification, except one or two examples of *Voltzia.* There are numerous fossils showing carbonaceous matter, that are probably the fruit of some plant, and a few fragments of an Equisetum-like stem. The most perfect example of this plant from the Trias is, however, the one figured in Morton's "Geology of Liverpool," and which was formerly in the collection in this building, but is now in the Free Public Museum. This was found at Storeton, and Mr. Marrat informs me that he has found remains of ferns there, that were, however, so friable that it was impossible to remove them. Within the last year or so a series of slabs of thin micaceous shales have been found at Flaybrick covered with the most confused markings, whose origin it is difficult to determine, probably because several causes may have contributed to their production on a soft expanse of wet sandy mud. They may be the tracks of crustaceans, worms or molluscs, or the result of running water, or a combination of both; but in the absence of animal remains it is dangerous to assert their organic origin. Amongst them, however, are some that undoubt-

edly present the appearance of impressions of Equisetum-like plants. I am enabled to shew you one of these, for which I am indebted to the kindness of Mr. Hornell. You will notice that there is no carbonaceous matter to be seen, and in its absence we may perhaps be wise to suspend our judgment.

Certain other cylindrical objects, hardened by the infiltration of iron, have from time to time been found, one as far back as 1844, and others within the last two years; but I think we should hardly be justified in asserting their vegetable origin.

The little exposure of the red marl at Woodchurch is well known to most of you. In a layer of very fine grey soft shale, less than an inch thick, which runs nearly the whole length of the section, Mr. J. Hornell and I found very numerous small lenticular bodies covered with a film of black matter, in some cases shewing a striation that gave an appearance of vegetable structure. When the black coating was removed they had much the appearance of flattened nodules of clay; however, the black film, which does not extend into the matrix, points to an organic origin. The objects are by no means rare and were found readily at each point where we examined the thin stratum in which they were first seen, and which may be readily recognised by its peculiar feel, resembling in this respect soapstone. The peculiar character of this layer would indicate a change in conditions for a short period and lends some slight additional probability to the supposition of their organic origin.

Plant remains have been found in shale of presumably Keuper age, viz., upper marls between High Peake Hill and Sidmouth, and are now in the Exeter Museum. They were found by Mr. P. O. Hutchinson,

and described by him in the Transactions of the Devonshire Association, to which I have been unable to refer, but they are mentioned incidentally by Mr. A. T. Metcalfe, F.G.S., in a paper on some vertebrate remains from the same locality.* He says: "It is manifest that "the remains had a verticilate ramification which pre-"supposes a verticilate foliage—facts pointing to the "Equisetiform type. As, however, the specimens are "structureless, their precise character cannot be deter-"mined with certainty." Mr. Hutchinson thus describes the specimens: "Stems of lacustrine plants discovered "in May, 1878, by a fall of some of the cliff. The "appearance on the slab of soft clayey and sandy rock "was that of a number of reed-like stalks lying across "one another, as if they had fallen into the water as "they grew. I secured a few pieces of the stems with a "joint or two in each, and the waves destroyed the slabs "soon after. The stems are an inch to an inch and a "quarter in diameter, oval by pressure; joints at every "six or seven inches, with indications that eight, nine, "or ten side branches grew out of each joint. The "interior of the fossils is soft sand rock, and the outside "is clay of a greenish colour." I have quoted the foregoing description at length, because it so nearly agrees with the appearance of similar fossils we have found in this neighbourhood, as may be at once seen by looking at the slab from Flaybrick that I have brought here to-night. The difficulty in both cases is the absence of structure, the fossils being I think, without doubt, the casts of impressions of the original objects, whatever they were.

I shall not now attempt to fully discuss the geological bearing of the very imperfect account of

* Q.J.G.S., vol. 40, page 262.

British Triassic fossils I have given you. But there is one thing that has been forcibly presented to me during the preparation of this address, and that is the enormous disproportion between the animal and vegetable life that must have existed in Keuper times, and that of which we have any trace left. Of the few animals which have left us their remains we know that some, and probably several, were carnivorous. As Professor Huxley has pointed out, *Stagonolepis Robertsoni* was undoubtedly a carnivorous reptile; it is unlikely he fed on lizards, yet in the beds in which its remains are found there is no record of other life than that of a few lizards.

Again, slab after slab of sandstone has been found covered with an endless array of footprints, not caused by the passage or re-passage of a few individuals, but from their diversity pointing to the presence of a numerous assemblage. Where then, did they find food? Carnivorous animals need herbivorous animals on which to feed, and they in turn require plant life for their support. Yet if we find the remains of the fauna scanty, those of the flora are comparatively infinitesimal.

With regard to life during the Bunter period we have no data to go upon, and to speculate upon it is hardly within the scope of serious geological inquiry. As to Keuper times we have here and there a glimpse which we hope may become in time a clear view.

These remains have been found generally where somewhat exceptional conditions appear to have prevailed. Shallow water was not an exceptional condition, but shallow water fairly free from mineral impurity was, and it is only in the neighbourhood of this that we could find an abundance of life. The Rowington and Shrewly fossils were found in a bed of light coloured rock,

between thick beds of unfossiliferous red marl. The attenuated Lower Keuper Sandstone of Warwick is light coloured, and lies between the red Permian marls below and the red Keuper marl above. The same thing occurs with the problematical objects from Woodchurch; the thin bed in which they occur was light coloured, and free from pseudomorphs of salt, which are abundant in the red beds above and below. If we adopt the theory of continental conditions prevailing in Keuper times, we shall find that it would be very probable that the areas favourable to animal and vegetable life would shift their position from time to time, would be limited in extent, and would *not* be areas of greatest deposition.

I merely put this forward as a possible explanation perhaps worth following up.

I have drawn up a short synopsis of the information I have received from curators and others connected with various provincial collections, to whom I am deeply indebted for the ready manner in which they very fully answered the inquiries with which I troubled them; and I am specially indebted to that veteran geologist the Rev. R. P. Brodie, for the facilities he gave me for seeing both his own and the Warwick collection.

The list may perhaps prove useful to any member who may attempt to prosecute enquiries connected with our local rocks which it has been my aim in this and my former address to encourage, and I hope that before long we may do something to work out one small chapter of that complete history of the earth, which is the great object of our science.

APPENDIX.

LIST OF PROVINCIAL MUSEUMS AND THEIR TRIASSIC FOSSILS, REFERRED TO IN THE PRESIDENT'S ADDRESS.

Bath Royal Literary and Scientific Institute:—
Rhynchosaurus Articeps.—Warwickshire.
Fish remains.—Elgin.
Ditto —Taunton.

Bristol Museum and Library, Queen's Road:—
Thecodontosaurus: the original type series.—Clifton.
Fish remains.—Nottingham and Warwickshire.

Bootle Free Museum:—
Fine series of footprints and casts of impressions of Integument (?)

Chester Grosvenor Museum:—
Series of Footprints, Annelid markings, &c.

Elgin Museum:—
Staganolepis Robertsoni.
Hyperodapedon Gordoni.
A quantity of Reptilian, &c., remains from the Neighbourhood, at present undescribed.

Edinburgh Museum of Science and Art:—
Ditto Geological Survey:—
Reptilian, &c., remains from Elgin. Amongst them are said to be those of Dicynodon.

Exeter:—
Plant remains from Sidmouth are said to be in this Museum.

Leicester Town Museum :—

Fish remains, Estheria, Tracks, &c., of Invertebrata,	Local.

Liverpool Free Museum :—

Collection of Footprints, Equisetum.—Storeton.

Nottingham Natural History Museum, University College :—

Fish, from neighbourhood.

Newcastle-upon-Tyne Natural History Society's Museum :—

Fish, &c., remains.—British.

(There is also an interesting series of fossils from the continental Trias, and some Dicynodont remains from South Africa.)

Shrewsbury Free Museum :—

Rhyncosaurus Articeps and footprints—Grimshill.

Warwick :—

The Series of local Reptilian, Amphibian, and Fish and Plant remains referred to in the Address, as well as a fine series of footprints from other parts of England.

GEOLOGICAL NOTES ON THE EXCURSION TO ANGLESEY, APRIL, 1889.

By T. Mellard Reade, F.G.S., &c.

A party, consisting of five of the members and a friend, spent the Easter holidays at Bull Bay, near Amlwch. During this time they examined the north coast of Anglesey, from Yr-hen-borth, west of Camlyn Bay, to Point Ælianus.

Slaty Series, North Coast.

Commencing at Yr-hen-borth, and working eastwardly, the strata occur in the following order:—purple grey and green slaty rocks in thin laminæ, apparently parallel to the bedding dipping 16° E., 35° N. Some of the purple slates at Yr-hen-borth were interpenetrated with igneous intrusions along the planes of lamination. In one case nine sheets were counted in a thickness of nine inches. It appeared as if the igneous injections had taken place along the bedding planes before the region had been subjected to upheaval and lateral pressure.

This phenomenon was very interesting, and I had a micro-slide cut at right angles to the bedding (Specimen No. 3), upon which Dr. Shearson Hyland reports as follows:—"The igneous mass has evidently been an acid one, and the intrusion has been prior to the general metamorphism of the district, for the rock bears evidence of having undergone considerable alteration, or deformation. The quartz of the igneous rock is almost wholly granulated, and this phenomenon may be well observed under crossed nicols.

The occurrence of hair-like needles of Sillimanite in the larger quartz grains is interesting. Felspar can hardly

be detected owing to the minuteness of the grain, but it is most probably present in no small quantity, and will be albitic in composition, a soda-felspar being the usual result of this kind of alteration. The granulated condition of this constituent is due to the mechanical stress the rock underwent subsequent to its consolidation from the liquid state. Where the limit of elasticity is not overcome, optical anomalies, such for instance as that of undulose extinction, are only apparent; where, on the other hand, this limit is passed, the mineral becomes resolved into a number of minuter "individuals," which are then no longer in optical continuity with each other. Stress or pressure is in fact transformed into heat, and the chemical energy awakened by the process induces a re-crystallisation *in situ* of the component substance. This is the phenomenon known as "granulation," and is specially characteristic of deformed rock-masses. Chlorite represents the original ferro-magnesian constituent. Iron pyrites are also observable. The yellow band in the centre of the section consists of epidote, due partly to the chloritisation of the ferro-magnesian constituent. The slate bears the normal character of such sediments. It contains a little rutile."

The slaty cleavage and the original lamination are coincident. This is apparent from the persistent dip of the rock, and the banded appearance due to the variation in colour of the layers. Further east the laminæ are driven into sharp horizontal overfolds. This structure is very perceptible on the face of the rock where it has been worn smooth by the pounding of the pebbles of the beach. At Llanrhwydrus a micro-slide of the rock shows a wavy undulating structure. (No. 8.) Dr. Hyland says of this:—"The quartz veins seem to "have suffered movement, but the irregularity of course

"they exhibit could be due to the injection of silica into "the fissures formed in the rock by the compression, "this injection naturally occurring subsequent to all "movement or influence of other forces."

Some interesting sections of drift occur at Yr-hen-borth showing boulder clay resting upon fragments of Anglesey schist packed together with a rudely parallel but contorted arrangement.

At Camlyn Point there is a very hard green schist dipping 12° E. 10° S., apparently interpenetrated along the bedding by thin igneous sheets. On the east side of Camlyn Bay purple slates are followed by contorted green schists, from which they are separated by a large igneous dyke. Good contact specimens can be obtained here (see No. 6). The dip of the purple slates is 22° N, 5° W. Specimen 13 is from the dyke, a massive rock much traversed with quartz veins. Of this Dr. Hyland reports: "I think this is the endomorphic alteration "product of the dyke itself. Igneous structure, if origin-"ally present, is entirely obliterated. Epidote, chlorite, "quartz, and (?) felspar compose the rock. Considerable "granulation of the quartz mass (? a vein) has occurred. "This quartz mass contains felspar, and is full of "liquid enclosures; this is a good illustration of the often "secondary character of these inclusions."

There is here an interesting section of slate and schist rubble, with potholes of laminated sand, the basal deposit of the drift.

Between Camlyn Bay and Cemmaes Bay, near a house occupied by the manager of the Guion Company, is a quarry for walling stone. This is of a cleavable slaty structure, having a dip of 25° N. 22° E. Close to, and a little higher up, is a second quarry of a similar rock, but inter-bedded with thicker and harder bands.

Specimen No. 1 is the green slate. Dr. Hyland says "this is a very phyllitic-looking slate, consisting "of minutely granular quartz, and a greenish sericitic "mica.

"There are a few octahedra of magnetite embedded "in the mass. Under high powers little granules and "needles of a pellucid mineral are to be observed. These "may possibly represent zircon and rutile, but the "minuteness of grain does not permit their definite "determination. A few microscopic veins of chlorite, as "also granular quartz, are observed to run through the "section, striking the foliæ at high angles." Of the thicker bands in the higher quarry (No. 2) he says, "Con-"stituents observed are quartz, iron pyrites, and a light "mica. A good deal of viridite present. Epidote is also "observable. There may be igneous material inter-"mixed."

At Cemmaes Bay are seen sections of Cemmaes limestone interbedded with sheets of volcanic ash, and further east are the large quarries in the Cemmaes limestone, which is burned for lime. Further to the east, and lying upon the limestone with an easterly dip, is a volcanic agglomerate of considerable thickness.

There are calcareous matter and irregular beds of limestone in the agglomerate. Towards its base these have been thrown over with an opposite dip.

At Porth Badrick we came upon a soft black shale which is I believe Silurian let down among the older rocks; but we had no time to search for fossils.

At Porth Llanlliana occurs a purple quartz conglomerate with shales lying thereon in an apparently unconformable manner and at a lower angle or, rather, in a long synclinal curve. In walking along the hill towards Porth-cynfor we cross a highly inclined quartz breccia

sediments derived from volcanic products, interpenetrated with igneous sheets and dykes, which have undergone much alteration through the combined effects of lateral compression and chemical action. It would also appear from the granulation of the quartz veins that there has been great compression at various stages of the metamorphism. This is only what one might expect, for the compression which gave rise to the North Wales mountain range did not occur till the close of the Silurian. If, then, these are Archæan rocks, much of the metamorphism they have undergone was impressed upon them in Pre-Cambrian times.

Again, the country has been covered with carboniferous rocks, the remains of which are to be seen at Moelfre and Red Wharf Bays. These rocks are also folded, though not so much so as the Silurians; but the carboniferous could not have been subjected to lateral compression without the underlying and older rocks having partaken of it. When we consider that these rocks were in a more rigid and crystalline state than the overlying rocks, it is not to be wondered at if they now possess mineralogical characteristics that are difficult to read, for they may have been subjected to very varying conditions and stresses, to compressive-extension, to flowing, and to shearing.

One of the interesting features of the slates is the parallelism of the bedding and cleavage; and I am in hopes that a further study of these rocks may throw some light on the difficult subject of slaty-cleavage.

I consider the series as sediments of volcanic origin, penetrated with contemporaneous igneous shales and dykes which have been subjected to repeated compressions and metamorphisms.

The relations I have shown to exist between sedimentation and upheaval here acquire additional confirmation.*

Old Red and Carboniferous.

The remainder of the time was occupied in examining these rocks between Amlwch and Moelfre.

Driving south-easterly from Amlwch, we pass in succession over the Crystalline Schists and Silurians, until at Dulas Bay we reach the Old Red Sandstone, of which there is a very interesting exposure on the left of the road. Whether this is really the equivalent of the Old Red or merely the base of the carboniferous, like the red beds underlying the carboniferous limestone in the Vale of Clwyd, we had not time to form an opinion. At Penrhos-lligwy the lowest beds of the carboniferous, according to the survey map, consisting of white quartz grit, are to be seen in a quarry. Some good specimens of slickensides, showing the cleavage and polishing of small pebbles or grains, were obtained. Glacial striæ, striking N.E. and S.W., were observed on the smooth surface of the sandstone above the quarry. Further on at a higher level, a quarry in the carboniferous limestone was visited; and on the coast south of Moelfre, the Penlleth quarries, now extensively worked for stone for the Manchester Ship Canal, afforded some interesting sections. One of the beds or "lifts" of limestone was not less than 12 feet thick of homogeneous limestone, offering a splendid opportunity for the quarrying of monoliths which would have proved invaluable to a race like the Egyptians. We, although possessing mechanical powers enormously in excess of anything the Egyptians could command, are content with more moderate sizes. The

* See "Origin of Mountain Ranges," pp. 71—78.

conditions of modern life make economy of more importance than grand, though comparatively useless, mass.

A final examination of the schists about Bull Bay completed a most pleasant and instructive excursion.

NOTES ON GLACIAL MORAINES.

By Linnæus Cumming, M.A.

This paper consists of an endeavour to trace the history of those remarkable heaps of material which are the constant attendants upon glaciers, and are called moraines. The general phenomena of glaciers, except in so far as they illustrate the formation or progressive history of moraines, is purposely passed by.

We will take first the origin of the moraines, about which there will probably be less room for difference of opinion than on other branches of the subject. The valleys through which the glacier travels are bounded on either side by rocky ridges, or plateaux, and it is to these we must look for the main blocks which compose a moraine, just as every cliff or steep rock slope in an inland valley has its talus of screes formed of detached rock masses; so these rocks, exposed to the alternate extremes of heat and frost, become gradually broken up, and the broken fragments are distributed over the surface of the glacier, extending only to a small distance from its edge. Every moraine, however, consists not only of large and small blocks, but these are held together—cemented is scarcely incorrect—by glacial sand and mud; this sand is peculiarly sharp and angular, and quite different from sea or river sand which has been rolled by running water. The presence of this

sand in the glacier is very easily tested by putting in the mouth a fragment of even the purest ice the glacier affords. After it has melted there will be found gritty fragments left behind peculiarly unpleasant to roll about with the tongue. In places too, the surface of a glacier is dirty with mire and sand, although half an inch beneath, the ice is to all appearance perfectly pure. To explain this we have only to look at a melting snow drift, or other thick accumulation of snow. There the surface becomes almost black with an accumulation of dirt, while a mere scratch through the dirt reveals apparently pure snow underneath. The snow as it drifts by the wind catches up fine particles of earth with it, which are very small in proportion to the volume of the snow, and are therefore overlooked while the snow is fresh. As the snow becomes compressed and melts the dirt accumulates on the surface, and we have in a thin layer the whole of the dirt carried in the thickness of snow which has melted. No doubt at these greater heights the snow is drifted by fiercer winds that we have knowledge of, since with us the wind is always retarded by friction against the earth. These winds catch up fine particles of sand from the upland rock surfaces, and these are hurried with the snow on to the névés, or glacier breeding grounds, as well as on to the glacier itself. Moreover where the snow collects in small quantities, or on sheltered surfaces, the heat of spring will often loosen the hold of the snow, which slides down on to the glacier as an avalanche, accompanied by large quantities of rock, as well as mud and sand. All this will be added to the bulk of the moraines.

This smaller material might be referred to the grinding and pounding of the stones which get embedded in the glacier. The writer believes that such detrition

does not go on in the mass of the glacier, because the stones in *fresh moraines* are rough, angular, and unpolished, as they fell from their parent rock masses. The polishing no doubt does occur at the base of the glacier, the bed-rock showing the polishing and striation so familiar in the valleys of Wales and Cumberland; but they are always on the rock bed, and not on the fragmentary material. The only stones which have a chance of being polished are those which come in contact with the rock bed, and their rarity in the resulting moraines supports such a view.

In the breaking up of a glacier which occurs in ice falls, for instance, the material ground out between the millstones (the nether, the rock bed, and the upper, the rock mass held in the moving glacier) will come to the surface or be distributed through the mass of the ice, but such material would hardly possess the sharp angular character of the moraine sand—it would be pounded rock and not grit.

One other point to be noticed in passing—is that the moraines are not formed of fragments broken off the rock bed by the advancing glacier. A glacier affords no evidence of power to do such work—as a friend of the writer has sometimes remarked—"A glacier is "the most sluggish beast in creation—it will do anything "to save trouble." It just rubs along as best it can, and rubbing is all we see in glaciated surfaces, large and small. In Norway we see hillocks which might have obstructed the glacier, and been broken off on the more active hypothesis, simply rubbed down into long whale-back-like hummocks, or worked by friction into Roches Moutonnées, each with its smooth polished surface, where it opposed the glacier's motion. In short, the action is purely frictional, not disruptive. We must

now turn to the progress of the moraine, which is at first a rough heap of material on the edges of the glacier. We must remember that the glacier is advancing truly, though slowly, and the material thrown down upon it is advancing too. No doubt, the medial moraines as they are called, or those which occur at a distance from the side, owe their origin to the uniting of the lateral moraines formed on the inner edges where a branch valley enters the main valley.

We now pass on to some of the surface characteristics of a glacier. The most prominent are the crevasses or cracks, by which it is split up to great depths. These are produced exactly as lines of fracture in other hard material, when the tensile stress between any two portions is greater than the cohesion of the mass can bear. The mass will then break up into cracks at right angles to the lines of greatest stress. These crevasses may be transverse, longitudinal, or oblique. The transverse crevasses are usually attributed to a sharp knee-

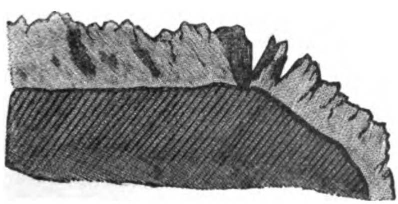


Fig. 1.

bend in the rock bed of the valley (Fig. 1.) In this case the upper part of the glacier will be stretched, and, as soon as the tensile strain of the ice is exceeded, will break into crevasses. Where the lower part of the valley is very steep, these lead to ice falls. They may, however, be produced by a sharp turn in the glacier valley, where continuity of the ice necessitates a more rapid rate of

motion in the convex than in the concave side of the glacier (Fig. 2.) But the nature of the glacier is to move most rapidly in the middle, where the ice is thickest and friction proportionally less. Thus we find the convex side of the glacier much broken.

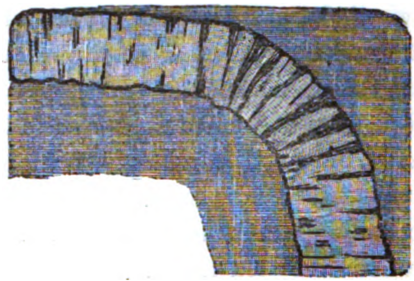


Fig. 2.

The longitudinal crevasses may be due to inequality in the rock-bed, making one part of the glacier much

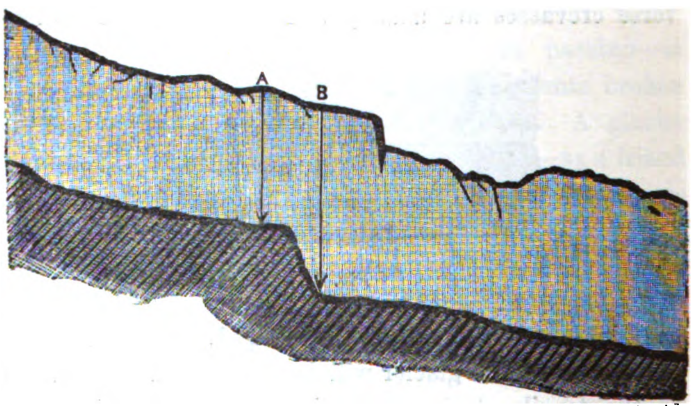


Fig. 3.

thicker than that adjacent to it. Then the ice at B (Fig. 3) will be much thicker, and will, therefore, move faster than that near A. The effect may be a breaking up of the ice

at A and B leading to a longitudinal crevasse. The oblique crevasses lie generally towards the edge, and are due to the more rapid movement in the centre than at

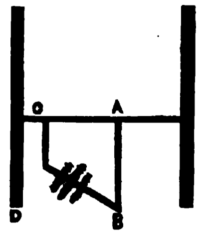


Fig. 4.*

the sides of the glacier. Thus while A (Fig. 4) in the centre moves to B, a point E near the margin will only move to D. Now, B D being longer than A C, the line joining these two points will, during the motion, be a line of tension, and crevasses may probably open perpendicular to it, or oblique to the general direction of the glacier. Whenever crevasses traverse a moraine, the material of the moraine is precipitated gradually, a block at a time into it, so that the moraines do not continue long as masses lying on the surface, but soon become completely frozen into the ice. Owing to the glacier's motion crevasses are continually closing, and others opening roughly in the same place, but composed of fresh ice.

Another surface feature to be noticed is the convexity of the glacier surface, so that one always ascends a convex ice slope in climbing from the rocks on to the glacier. This is always composed of relatively pure ice, the moraine always being at some little distance from the edge; though, of course, any loose fragments of

* Note.—In Fig. 4 the point D should be at the obtuse angle between B and C.

stone which have recently fallen cumber this portion of the glacier. With some hesitation the writer attributes this feature of the glacier to the radiation of heat from the rock faces, which leads to an increased melting of the ice in its neighbourhood. The existence of the moraines in the lower part of the glacier valley at a distance from the sides of the valley may be explained by the drag along the line B D (Fig. 4), by which we explained oblique crevasses, all the marginal ice being dragged on, as far as its strength permits, towards the centre. There is, however, another cause which may contribute to produce both effects. This is the existence under the glacier, especially in the central part of the valley, of a rapid water torrent. The water formed from melting ice on the surface, through the crevasses, finds its way down to swell this torrent. By its friction, and also by its being ever so little above the freezing point, it hollows out a large cavern extending all along the central part of the glacier, which during a large part of the year will be nearly vacant. By all we know about ice, which on the large scale, and allowed sufficient length of time, behaves like a plastic body, the permanent existence of such a cavern seems very unlikely. One would expect the ice to be drawn in from the sides to constantly close this ever-increasing sub-glacial hollow. This constant drawing from the sides towards the centre would give a convex surface near the edge, and would displace the moraine lines bodily from the edge towards the centre, and would explain many cases of longitudinal crevasses.

On viewing a glacier from a distance we notice dark lines running down it, in contrast to the general white surface. These are the moraine ridges which, at first sight at any rate, appear above the general surface of the ice. These are not mere heaps of moraine material, but

ice surfaced with stones, large and small, frozen into the ice, which is coated with fine débris an inch or two thick, exhibiting under it as pure ice as the rest of the glacier. It must not for a moment be thought that these ridges are really the heaps of moraine matter originally thrown down on the glacier and carried to their present position by the glacier's progressive movement. The original material has, by the action of crevasses and ice-falls, been kneaded through the mass of the ice before it reaches the lower levels at which we are able to observe. The surface ridges are certainly due to differential melting of the ice; and this necessitates a few words about the effect of rock débris in hindering or hastening surface melting. Large blocks of rock no doubt retard the melting of the ice if their surface slopes at all southwards, and so breaks the sun's rays. The reason is that they protect the ice underneath from the direct action of the sun, and deflect to either side the runnels of water over the surface by which much of the surface melting is effected. The action of the sun does not last long enough to heat through the block, and so to melt it by conduction, and we have the familiar ice tables so well known on most glaciers. On the other hand, much smaller fragments accelerate the melting, and we see on glaciers numerous pools with vertical sides, each having a stone at the bottom. Here the stone is each day heated by the sun, and raised above freezing point, thus melting some of the ice round it and causing the stone to sink into the ice surrounded by the pool of water it has melted. The same thing happens on each succeeding day. The stone receives the rays of sun heat transmitted through the water, and warms the water round it, causing it to melt more and more of the ice. Yet, again, a coating of fine sand or gravel has a

remarkable power of protecting ice. The difference seems to be that this material holds water, and is wetted by the water derived from the melting of the ice beneath. The rays which fall on the stratum of wet sand are obstructed, none directly reaching the ice, and they are used up in drying the surface of the sand by evaporation of water. The consequence is an extremely slow rate of melting of the ice so covered up. In illustration of this, it is not uncommon to observe on glaciers miniature mountain ridges 6 to 10 feet high, and very steep sided. These appear at first sight to be composed of sand, but on touching them the coating is found not more than half an inch thick, under which is very pure glacial ice.

It has been pointed out that the moraine lines appear on the glacier as prominent ridges, but the writer has noticed appearances in one or two cases lately which led him to doubt whether the ridge was not more apparent than real. Thus, it has been noticed that the ice slopes down towards the moraine much as it does towards the rock on the side of the valley. So that, if a general level were struck, the moraine ridge might be little either above or below the general level. This, with great hesitation, is attributed to the heating of the rocks in the moraine by the sun, and these by their radiation increase the melting of the ice near them.

In referring the melting of a glacier to direct radiation it should be remembered that the ice is never clear and transparent, but highly granular and full of air cavities. The radiation will therefore be absorbed close to the surface, and melting will proceed there.

We have noticed the history of the moraine as long as it remains bedded in the ice. Now we must trace its deposit at the snout of the glacier. It is only when so deposited that it becomes a geological agent of any

importance. The melting of the ice at the snout of the glacier causes the rock débris which has hitherto been imbedded in the ice to be thrown down, and it is to the mounds of such material below the end of the glacier that the term moraine more properly belongs. If the position of the snout, or melting point of the glacier, were for many years stationary such accumulation would cover up completely the end of the ice, making a dam across the valley. This may very likely be the source of some so-called terminal moraines noticed by geologists, but which the present writer has never seen in process of formation.

Geologists, however, have only to do with the relics left by retreating glaciers, as in all cases the glacier has long ago vanished when the geologists begin to conjure up the past history of a valley. Luckily nearly all the glaciers of Europe, which are generally visited, are now and have for years been shrinking. Thus we may expect to find in the glacier valleys of the present day the counterpart of those phenomena familiar to geologists, and quoted as proofs of former glaciation.

The following observations of a valley with a retreating glacier is taken from the Breslau glacier, a small glacier in the Oetzthal group in Austria, which the writer visited last August. The moraine mounds down the valley are seen to be the continuation of the moraine lines, which can be perfectly well traced on the glacier from a point where we have a bird's eye view of the glacier and its valley. The lateral moraines are not immediately along the side of the valley, but are always separated by a narrow valley, which is strewn with rocks which have probably fallen to their present position from the sides of the valley, and not having been transported on the glacier, are not properly moraine at

all. The lateral moraines never reach the side of the valley except when another branch glacier joins. The

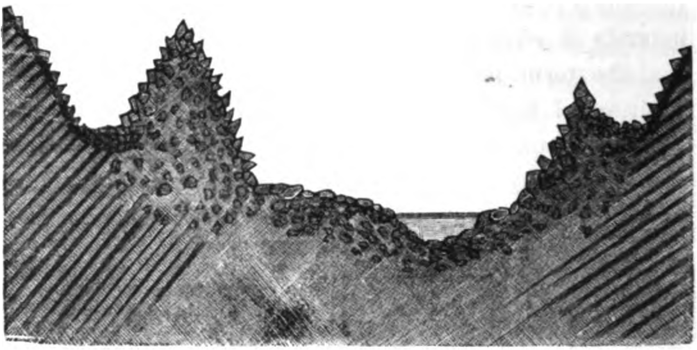


Fig. 5.

diagram shows a section of the valley at a lower point. It may be taken as typical of what we constantly find in these valleys. The two moraine mounds stand up as shown. The slope of the sides varying from 30° to 42° in different moraines where measured. The surface of the valley is made of moraine material, through which flows the stream of water from the glacier, highly charged with glacial mud, which gets deposited when the speed of the stream is slackened. The moraine heaps are by no means heaps of loose gravel, but are remarkably hard, some of the finer material acting as a cement in which the fine, sharp, glacial sand is set, giving the whole surface a harsh, gritty feeling to the touch. At the same time the surface bristles with boulders of all sizes remarkably angular and unworn. The writer has never noticed a block either polished or striated. These mounds with tops so sharp that foothold is difficult to find are not pleasant to walk along, and after a few hours of such walking one begins to sympathize with the small Rugby boy, who recounted among the Egyptian plagues a "very grievous *moraine*."

Across the valley of the Rofenhaar glacier adjoining that of the Breslau glacier, runs the path from Fend to the Breslau Hut. Tracing the path towards Fend you first cross the lateral moraine, the slopes of whose sides were measured and found to be 42° on one side and 32° on the other. The angle 42° is remarkably steep for material to maintain, as it must have done for many years, under the influence of atmospheric denudation. Following this moraine was a considerable mass of rock certainly *in situ*, with its surface rounded and smoothed, but not at all broken. Such masses as these are often visible in valleys actually covered by glacier, as they lead to ice falls in which the rock surface is exposed. The rest of the comparatively wide valley consists of a series of rounded hummocky longitudinal hills, with another well-formed moraine dividing the valley into two nearly equal portions. The inclinations in this moraine were by measurement 39° and 30°, still steep but less so than that on the side of the valley. The long hummocks were different to the moraines on either side in being rounded instead of having sharp steep slopes, also in having their smaller stones rounded more or less as by water action, the larger blocks alone retaining some trace of their angular character. From their position it was impossible to believe they were not formed of moraine material, and where the stream made a section through them their moraine character was obvious. Possibly they might be moraines which were fast disappearing by the action of running water, which could easily have swept the whole valley in spring when the winter snow accumulation melts. The preservation of the central moraine noticed above was apparently due to its lying at a higher level, and therefore above the general sweep of the water.

The observation of this hummocky ground reminded the writer of the head of the Justedal valley in Norway. After crossing from N. to S. the great Justedal glacier, we descended by the Lodal's Bracen to the valley. On descending from the ice we saw no moraines, not even the lateral moraines, but a wide expanse of practically level ground surfaced with glacial mud, intersected in all directions by a network of streams. This formation was attributed to a vast flood of water sweeping over the valley in the spring, and redistributing all the moraine material deposited by the glacier, and covering it up with glacier mud, the water of the glacier stream moving slowly over the nearly level valley.

This observation explains formation of the terraces which occur so plentifully in all the valleys of Norway, that it is hardly an exaggeration to say that every flat arable piece of land is one such terrace. The internal structure of these terraces can easily be examined by natural sections, and is found to consist of a mixture of stones of all sizes more or less rounded and smooth, with abundance of gravel. The materials no doubt, are those of a glacial moraine, but worked by water and re-distributed. This would certainly be the structure of the flat land below the Lodal's Bracen, and it took little imagination to see that the constant filling up of the valley would restrict the water to one or few channels, which would by scouring, cut their way deep into the deposit, leaving on either side a steep bank with flat land on the top. These would retire further and further from the stream, and would form just the terraces so characteristic of every Norwegian valley.

To call material of this latter description glacial moraine, unless when obviously associated with a glacier or other glacial phenomena, is a misuse of language.

It is undistinguishable from ordinary detritus which has been water-worn, and it would be vain to look among it for polished or striated blocks, all such markings being of necessity eliminated in the more recent process of rounding and smoothing by water. Even the admixture of stones brought from a distance up the same valley is not conclusive, if we bear in mind the enormous transporting power of streams when flooded; while if the stones—as in the boulder clay of the Midlands—are carried from great distances, and from localities not associated with the valleys in which they are found, such deposits are certainly not glacier moraines, such as have been referred to here.

Remains composed of sharp, angular blocks and gritty, glacial sand, such as anyone familiar with glaciation abroad would at once recognize as moraines, are, as far as the present writer knows, very rare in our own country.

One point more, in conclusion. We find, as is well known in valleys where traces of glaciation abound, lakes with rock bottoms smoothed by ice action, and it has not been unnatural to attribute such lakes to the hollowing or scooping action of the glacier in passing down the valley.

In many Norwegian valleys whose upper ends are occupied by glaciers, such lakes occur, and it is very difficult to attribute their presence to any other cause. Having in the last twenty years visited very many valleys such as these, both in Norway and in Central Europe, the writer has never seen one such lake in process of forming, as for instance a glacier ending in such a rock-bottomed lake which increased in length as the glacier retired.

NOTE ON A BOULDER MET WITH IN DRIVING A SEWER HEADING IN ADDISON STREET, LIVERPOOL.

By T. Mellard Reade, F.G.S.

In erecting the new Day Industrial Schools for the Liverpool School Board, of which I am the architect, it became necessary to divert an old sewer from under the site of the main wall in Addison Street. A new heading was driven a distance of about 100 yards along Addison Street, opposite the site of the School. Towards the lower corner of the site a large boulder, determined by Prof. Judd to be a much altered volcanic tuff, was found lying directly across the course of the heading. It was 22 feet 7 inches below the surface of the street, measuring to the bottom of the boulder. The stone itself measured 4 feet 10 inches by 3 feet by 2 feet 6 inches, and was probably from 1½ to 2 tons weight. It lay on its flat side nearly horizontal, with its longer axis obliquely across the sewer, having a direction about 32° west of north.

It was embedded in compact boulder clay, having a sand seam of a few inches in thickness towards the top of the boulder. Immediately under it was laminated clay, then boulder clay, then laminated clay, in all about 1 foot 3 inches thick. Below this was red sand from the decay of the Trias graduating into red rock having two thin veins or bands of grey rock in it not far from the horizontal.

The boulder clay existed up to within about 5 or 6 feet from the surface, and in it was a bed of sand about 12 inches thick.

The boulder clay and sand varies very much in different lengths of the sewer, a thicker bed of sand occurring at the western end of the heading, in which are small shell fragments.

The main interest of this example exists in the axial lie of the boulder, which is approximately in the direction of the grooving and striæ found on the Triassic rocks in other places around Liverpool where they have been preserved.

It was at first intended to break up the boulder, but this was found too difficult, therefore a pit was dug in the rock below and the clay hollowed out around the boulder, it being temporarily propped up in position. Into this pit it is now dropped.

In future ages if an enterprising geologist comes across this specimen, it will no doubt give rise to some curious theories. Some will perhaps contend that the cavity in the rock is a glacial pot hole, or a pit washed out by the whirling round of the boulder by sub-glacial streams! With this prospect in view it will be perhaps better for us moderns just to leave this description where it is, and for the nonce decline to theorise as to how exactly the boulder came to be orientated in the direction of the glaciation of the country. There appears to be no disturbance of the boulder clay in which it lies, such as would be produced by the pushing along of the boulder; the stratified sand seam rather points to quiet conditions prevailing and to sedimentation.

It is so seldom one gets a chance of properly observing a large boulder *in situ*, that every opportunity should be taken to ascertain and record the direction of the longer axis in such cases, and I would earnestly commend this to the attention of the Boulder Committee.

REMARKS ON THE CONTORTED SCHISTS OF ANGLESEY.

By Charles Ricketts, M.D., F.G.S.

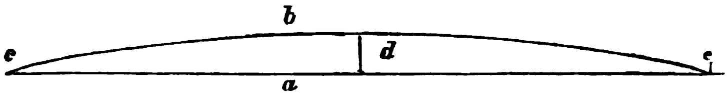
During the excursion of our Society to Anglesey it was noticed that along the whole extent of the northern coast, from beyond Camlyn Bay to Point Linas, the strata, though varying as to the angle, dipped continuously towards the north; and that until at its eastern extremity the latter place was reached, there was very little, if any, indication of what may be considered contorted strata. Here a complete contrast occurs to what had been observed along the northern margin. The strata consist of thin layers of variously tinted bands, bent abruptly in a zigzag fashion into numerous folds; the layers passing continuously at the angles render the beds thicker there than on the sides. This bending has occurred without displacement and without fracture at the angle. These remarkable corrugations, with the same acute angles, were traced in all the knolls situated in a line from Point Linas and the village of Llaneilian as far as to the southwest of Amlwch, a distance of at least three miles (the examination was not continued further). The strike of the beds is nearly east and west, about the same direction as along the coast.*

Contortions and bendings of strata are very generally attributed to secular cooling of the earth's mass, the resulting contraction being supposed to cause its crust to

* These flexures are illustrated in Mem. Geol. Survey; Vol. 3. (1st Edit.), page 187, fig. 85.

occupy a smaller space as the size of the earth in cooling became lessened. The improbability, or rather impossibility, of contortions occurring to the extent assumed from such or a similar cause was demonstrated before

Fig. 1.



this Society during the session of 1887-88,* "by taking "two slips of wood (Fig. 1, *ab*) of equal length, say 10 "feet, fastened together at one end by a hinge (*c*); one "(*a*) being fixed so as to remain straight, the other (*b*) "bent to represent a segment of a circle, the greatest "distance (*d*) between the chord (*a*) and the curve (*b*) "being six inches; it will be apparent that the distance "between the extremities of the slips of wood will be "very slightly over three-quarters of an inch (*e*);" that is, only about $\frac{1}{160}$th part of the length of the unbent lath.

They have also been ascribed to the action of internal heat, causing expansion and consequent compression of the earth's crust. If a calculation made by Babbage† is approximately correct, the expansion of a mass of granite 25 miles thick, heated to 1000° Fahr., would amount to only 637 feet. Such comparatively slight changes could in no way account for the great flexures occurring in stratified rocks. It should always be kept in mind that as all rocks do not expand by the accession of heat, it is likely that aluminous earths which contract on being heated will greatly modify the effects of increase of temperature on other substances.

* The communication was incorporated in "Some Physical Changes in the Earth's Crust," by C. Ricketts; Geol. Mag., Feb., 1889.

† Ninth Bridgewater Treatise, page 222.

Granting the possibility that these causes—secular cooling or increase of heat—could have induced flexures similar to, and so excessive as, those seen at Point Linas, &c., the compression thus induced must have acted simultaneously on all sides; therefore, there ought to have been, under the circumstances, similar flexures in different directions. The strike could not have continued virtually the same for eleven miles, as was proved to be the case.

Abrupt flexures, very similar in appearance, are not uncommon where there is no indication of exposure to intense heat. Dr. James Hutton, in his "Theory of the Earth,"* represents, from a drawing by Sir James Hall, a section at St. Abb's Head; it is that which suggested to the latter the theory now universally accepted, that flexures of strata are caused by lateral pressure. The foldings are on a much larger scale, but as abrupt as those of Anglesey. A similar example is that at Draughton, near Skipton, in Carboniferous Limestone; sketches of which are given by Mr. H. B. Woodward in "Geology of England and Wales," 2nd Edit.; by Mr. T. Mellard Reade in "Origin of Mountain Ranges;" and in "Research" for July, 1889, by Mr. O. W. Jeffs, who also exhibited to us a photograph of such flexures in the chalk at Flamborough. Further examples have been given by Sir Henry de la Beche, by Jukes, and others.

It does not appear that in any of the examples here referred to, the flexures can have been due to the action of heat. It is possible that the *angularity* of the flexures may have been dependent on, or influenced by, the amount of solidity of the rock mass at the time lateral compression occurred. Because the strata at Anglesey

---

* Vol. 1, Plate 4.

have been subjected to metamorphism, and that is attributable to the effects of heat, it must not be at once concluded that the contortions have likewise been due to the same cause.

It is worthy of investigation by the examination of these and other metamorphic rocks, whether the inclination of the strata and also the flexures have originated previous to metamorphism, whilst the sediments were unconsolidated, from such a cause as that advanced during the session of 1887-1888 to account for the occurrence of flexures in stratified rocks.* It was then proved by models, the result of experiment (Fig. 2), that contortions of strata might result from the deposit,

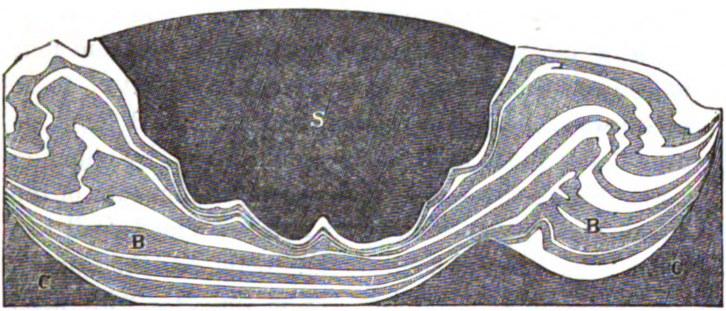


Fig. 2. C, consolidated clay; B, layers of clay, originally in horizontal beds, but squeezed into folds by the vertical pressure of S, sand (extra weight being applied).

heavier and in larger quantity, of materials brought down by river currents, and deposited sea-ward along their course; the greater weight of such ingredients, as sand and gravel, causing a pressing downwards of the plastic accumulation beneath, and at the same time squeezing outwards and forcing upwards the unconsolidated and muddy strata along the margin of depression.

* See "Changes in the Earth's Crust," Geol. Mag., April, 1889.

NOTES OF EXAMINATION OF WATER FROM THE RIVER ARVEIRON, NEAR ARGENTIÈRE, AND OF DEPOSIT FROM THE BED OF THE SAME STREAM.

By P. Holland, F.C.S., F.I.C., and E. Dickson, F.G.S.

The River Arveiron has its source in the Glacier des Bois, and issues from beneath an arched tunnel in the ice near the village of Argentière, which is about four miles from Chamouni. The water (the subject of these notes) was collected in August, 1888 by Mr. Holland, as near to its source as it was possible to get, by plunging a wide-mouthed vessel in mid-stream, the breadth of the stream at the place being about 20 feet. The deposit was taken from different points *in* the stream, and then mixed. The water of the Arveiron, as is the case with most glacier streams, has a very milky appearance, and it was in order to examine the material causing this milky appearance, and to ascertain the amount, that we were led to take a specimen of the water; for it was obvious that, whatever might be its nature, suspended matter was present in very considerable quantity. The stream varies in volume at different periods of the year, the volume being less in the spring and winter than in the summer and autumn months. Professor Forbes estimated that in the month of September, 1842, when he made his examination, the volume of the stream near its source was about 300 cubic feet a second.

The water when collected by Mr. Holland was quite opalescent, but the matter in suspension was so finely divided that when the water was shaken, it did not again become clear even after standing for 48 hours. A microscopical examination of the matter in suspension shewed angular particles of quartz, felspar, augite, &c.—quartz, however, forming by far the greater portion.

The amount of suspended matter was found by passing a measured volume of the well-shaken water through a previously dried and weighed filter, which after again drying was re-weighed. Determined in this manner, the suspended matter was found to 14·2 grains per Imperial gallon, that is to say, 18 cwt. 12 lbs. 8 oz. per 1,000,000 gallons, or put in another way, 88·7 grains per cubic foot; so that taking Prof. Forbes' figures of 300 cubic feet per second as the rate of flow of the stream, this impalpable matter carried down reaches no less an amount than about six tons per hour.

The matter *dissolved* in the water (that is to say, the saline matter) was estimated in the clear filtrate by evaporating this to dryness, and amounted to 4·18 grains per Imperial gallon, or 5 cwt. 37 lbs. 2 oz. per 1,000,000 gallons, or, on the basis of Prof. Forbes' figures as above, 1 ton 14 cwt. per hour. The saline residue gave the spectral reactions of potash, lithia (faintly), and soda.

The sedimentary matter collected at the edge, and which was similar in character at various points of the stream where examined, when dry appeared to consist of a fine grey sand made up of *angular* particles. Examined qualitatively, the sand contained, besides silica, both ferrous and ferric oxides, alumina, manganous oxide, titanic oxide, lime, magnesia, potash, and soda. The spectroscope also indicated traces of lithia (faintly).

A chemical examination of this sandy material gave the following result:—

SiO_2	.. ..	80.82
Al_2O_3	.. ..	10·26
Fe_2O_3	.. ..	1·34
TiO_2, MnO, K_2O, Na_2O, Li_2O, CaO, MgO	Difference	7·58
Combined Water	.. ..	—
		100·00

The specific gravity of this sandy deposit is 2·82, slightly higher than that of quartz. It was noticed during the analyses that the sand yielded but little alumina to dilute hydrochloric acid, from which it might be inferred that the bulk of this oxide, represented by 10·26 in the foregoing figures, is not present as a product of decomposed felspars which go to form clay, but is intact as one of the original rock-forming substances, the sandy matter itself being the abraded particles of such rocks.

If we compare the above analysis with potters' clay and Stourbridge clay (both of which are considerably acted upon by dilute hydrochloric acid), we find that Stourbridge clay contains $^0/_0$ SiO_2 65, Al_2O_3 22, and potters' clay $^0/_0$ SiO_2 49, Al_2O_3 32, which facts go to shew that the siliceous matter in question is in no sense a clay.

Unfortunately there was not a sufficient quantity of water collected to make a full analysis of the water itself, which contains in all probability alumina in solution; but we trust that in a future session of the Society we may be enabled to complete the examination of the water of the Arveiron, and give some results of the examination of other glacial streams.

MICROSCOPICAL EXAMINATION OF TWO GLACIAL BOULDERS.

By I. E. George.

1.—Pen-y-bont, Ruabon: Granite Boulder.

On one side of the clay-pit excavated in the Permian Marl at Mr. J. C. Edwards' Terra-Cotta Works, there is exposed a section, about six feet in thickness, of a "Conglomerate drift," a deposit which seems to represent a concentration of glacial boulders. Two very large blocks of grey Felsite are conspicuous on the ground, and would probably be classed as Arenig. The bulk of the smaller ones consists of Silurian grits, and the whole series are such as might have been derived from the Silurian rocks of North Wales. In a section differing so markedly from local Boulder-clays in the absence of the coarse-grained northern granites, Dr. Ricketts and myself were interested to see a round boulder, some twelve inches across, pinkish in colour, and apparently granitic. A section of this rock was prepared and submitted to Dr. J. Shearson Hyland for microscopical examination and comparison, with a special view to the determination of its place of origin. From Dr. Hyland's report we learn that the rock (which is a fine grained granite, with the addition of plagioclase, and having its biotite altered to a chloritic mineral) is not identical in structure and composition with any of the better known masses of English granite. It shows a development of the micro-pegmatitic structure, resulting from the simultaneous growth of its quartz and felspar crystals, and this peculiarity is found in the

granites of North Wales and North Pembrokeshire, as well as in those of Mull and the Mourne Mountains. It would appear then, that there is no reason to localise the source of the granite boulder out of North Wales, where the remainder of the boulders seem to have originated.

2.—Felsite Boulder, Mayer Library Walks, Bebington.

One of the largest amongst the boulders now ornamenting the Mayer grounds, is a large block of Felsite, about 3 feet square, originally brought from the neighbourhood of Raby Mere, Cheshire. It is described by Dr. Hyland as an altered Felsite, porphyritic, with a micro-felsitic ground mass, and epidote as an alteration product. To locate the parent mass would be impossible, as the specimen in no way differs from the ordinary Felsite.

WHAT BECOMES OF THE WATER EJECTED FROM VOLCANOES?

By H. C. Beasley.

The theory lately advanced of the increase of the volume of the ocean by the accession of water drawn from the interior of the earth by volcanic action has such an important bearing on the right reading of the geological record, that I trust I may be excused for drawing attention to a possible answer to the question at the head of this paper; and that is that the loose material thrown up by the volcano forms an addition to the upper strata of the earth's crust capable of retaining moisture equal in quantity to the water ejected.

Very frequently the first external phenomenon noticed in a volcanic outburst is the sudden uprush of a column of steam carrying with it a great amount of finely comminuted matter, together with rock fragments of all sizes. Instances of the enormous amount of this volcanic dust will readily occur to you all. The steam is partly carried away as clouds, and partly precipitated at once in torrents of rain, which, mingling with the dust, has formed those streams of mud that have wrought perhaps more destruction, and are really more dreaded, than streams of lava. We seldom, however, hear of great floods of water caused by the downpour of rain. The more important floods accompanying volcanic eruptions have been caused by the sudden melting of the snow and ice that cover the more lofty volcanoes, or by the temporary damming up of streams by the ejectamenta of the volcano.

The production of this vast amount of dust is in many text books put down as the result of the attrition of large masses of rock against each other and the sides of the vent; but, as Dr. Geikie has pointed out, this seems an inadequate cause; and it would be well to inquire what would be the behaviour of a rock more or less saturated with moisture and heated under pressure, when the pressure was suddenly removed. I should expect that it would be instantly rent into fragments mostly so small as to constitute fine dust. Now this is just what I conceive takes place in one of the earlier stages of a volcanic outburst. The greater part of the water ejected is now, however, generally supposed to proceed from the liquid lava; but the overlying rock having been removed, the lava itself, if it contained water, would behave in the same way, and the steam rushing upwards would carry with it portions of the

lava torn into minute fragments, constituting that pumiceous powder so characteristic of volcanic ash.

Does the water so liberated eventually swell the volume of the ocean? I think not, for it has, as we have seen, brought with it, as it were, the sponge that held it far within the crust of the earth, and will now hold it on the surface. Doubtless a far greater proportion of water has reached the surface than of the rock that held it, and when the first outburst is over large quantities of steam will continue to be emitted without the force necessary to bring solid matter with it; but the amount of solid matter thrown up is in a condition to form a far more absorbent rock than it originally was. A portion of the vapour emitted will be carried away by the atmospheric currents and find its way to the ocean; but we are not dealing with immediate results, and if the soil and rock added to the superficial portion of the earth's crust eventually absorbs and holds permanently in its interstices an amount of water equal to that thrown out by the volcano, the result will be the same as though none whatever found its way to the ocean.

RECENT DISCOVERY OF A BONE CAVE AT DEEP DALE, NEAR BUXTON.

By J. J. Fitzpatrick.

In all parts of the world where the Carboniferous Limestone is found caves and caverns are to be met with in the rocks, and many discoveries relating to the antiquity of man, and the history of those animals whose remains

are often found associated with his, are made. These bones, owing to favourable surrounding conditions, are sometimes in an excellent state of preservation. Such discoveries are of the utmost importance in connection with the history of recent life upon the earth, and more especially in relation to fixing, as nearly as possible, the time when the first representative of the human race made his appearance.

The caves of Derbyshire have yielded many objects of interest, and fresh discoveries are from time to time being made. It sometimes happens that these hidden things are brought to light in the most simple and unexpected manner; and this was so in the case of the cave which I am about to describe.

Deep Dale is a wild, rocky, and romantic gorge near Kingsterndale, and situated about three miles from Buxton. It is about one mile in length, and varies in width from 100 to 200 yards. The deepest part of the Dale is 900 feet above sea-level. The rocks in many parts rise perpendicularly to a height of 160 feet.

The cave in question is situated about three-quarters of a mile from the Bakewell Road, and half-a-mile from the London Road, on the left, going from the former to the latter. The entrance to the cave is about 20 feet above the stream which flows through the Dale towards Topley Pike, and the height of the perpendicular cliff which rises above the cave is about 140 feet.

The cave, which runs horizontally into the rocks in a direction almost due east, is not marked upon the one-inch map of the Geological Survey, but it is represented on the 6-inch Ordnance map.

Deep Dale has always proved an attractive and pleasant place of resort for the youths of Buxton, who, at all

times of the year, but particularly in the summer and autumn months, visit it in large numbers.

Mr. William Millett, of Buxton, a youth now nearly nineteen years of age, has been in the habit of exploring the Dale for the past three years, and he frequently visited this cave, which has long been noted for the size of the main entrance. He carefully examined by the light of a candle every part of the two largest chambers, and having on several occasions found some curious objects, such as Roman pottery and Samian ware, he continued his visits with renewed interest. In his search he used a small pick, and on examining a small hole or opening in the stalagmitic sheet, which covers a large portion of the floor of the second chamber, he broke off some pieces of stalagmite, and was surprised to find that there was a dark cavity underneath.

With a little exertion he enlarged the entrance to this opening or narrow tunnel, which formed the passage to another or third chamber, to which he lowered himself by the assistance of a rope.

He still persevered, and from the third chamber he entered another narrow passage, through which only a boy could pass, into a fourth chamber. In this there was a quantity of broken stalagmitic matter, and near this he found a skull of a Celtic shorthorn (*Bos longifrons*), the antler of a stag, and a bone spear-head.

For many months and with the greatest possible exertion the young explorer kept at his work, and succeeded in gaining an entrance to a fifth chamber, in which he discovered a portion of the skull of a wild boar (*Sus scrofa*), and near it a splendid skull of the brown bear (*Ursus arctos*), in an admirable state of preservation, and embedded in a large piece of stalagmite, which covered it to a depth of nearly 4 inches. The skull

shows the bones and teeth to perfection, and it is quite evident that this bear lived to a good old age and was a sufferer from tooth-ache, as two or three small round holes penetrating through the enamel and the dentine in some of the teeth plainly show. The teeth are much worn down. The piece of stalagmite in which the skull was found is perfectly white, and the hollow into which the skull fits indicates the exact surroundings which have preserved for ages this valuable specimen.

Below the fifth chamber Mr. Millett found a sixth and last, at the bottom of which there is a well 6 feet deep.

At my suggestion he measured as carefully as possible the sizes of the various chambers, beginning at the main entrance. The height of this entrance is 12 feet, and the width 20 feet. The length of the first chamber is 93 feet, and the width from 10 to 20 feet, the height from 6 to 12 feet. The second chamber is 73 feet in length, from 12 to 20 feet in width, and from 8 to 12 feet in height; in one part to the left from the entrance the chamber rises to a height of about 35 feet. The third chamber is 17 feet in length, 4 feet in width, and 7 feet in height. The fourth chamber is 19 feet in length, 3 feet in width, and from 3 to 5 feet in height. The fifth chamber is 49 feet in length, 6 feet in width, and from 8 to 12 in height. The sixth and last chamber is 13 feet in length, 10 feet in width, and 9 feet in height.

Some of the objects discovered were more or less embedded in stalagmite. Several of the bones crumbled into dust on a short exposure to the atmosphere. Young Mr. Millett had the objects of interest found by him placed on a large table in the parlour of his father's house, where after my first visit to the cave I had the pleasure of examining them. The collection has been disposed of within the last few weeks in a very

satisfactory manner. A new town hall having just been built at Buxton, and a portion of it set apart as a museum, Mr. Millett informs me that he has presented his collection to his native town.

A sensation was created amongst the youths of Buxton by the discoveries, and some of these, emulating the ardour of Mr. Millett, have become cave-hunters, but the exertions required to penetrate into the lower chambers of the Deep Dale Cave, and the damp and slimy condition of the various passages to the chambers, make the work a very unpleasant one.

Amongst the chief objects of interest discovered in the lower chambers of the cave are a skull of the brown bear (*Ursus arctos*) in a good state of preservation, a skull of the Celtic shorthorn (*Bos longifrons*), bones and teeth of the reindeer (*Cervus tarandus*), and of the red deer (*Cervus elaphus*), part of a skull of the wild boar (*Sus scrofa*), human bones, and a slate arrow head. In the upper chambers there were found a cut stag horn, hand-made pottery, a Roman pin ornament, Samian ware, Romano-British pottery, and pieces of charcoal. Several pieces of charcoal were found embedded in stalagmite. Some of the hand-made pottery shows the finger marks of the maker. There were also found bones of birds, sheep and goats. Mr. Wilson, a friend of Mr. Millett's, found a Roman coin dating from A.D. 250. This is important, as indicating the Roman occupation of the cave.

In a communication which I received from Mr. Millett at the end of January, he states that in the last week of December, with the assistance of his father, Mr. Robert Millett, he dug a large hole, 8 feet in depth, in the floor of the second chamber, and a section shows the upper bed, which is 3 feet in thickness, to be composed

of dark clay, with angular fragments of limestone. In this bed there were found Roman pottery, a bronze ring, a bone pin, a bronze locket, and the remains of the stag, horse, sheep, goat and boar. The second bed is from 6 to 18 inches in thickness, and consists of broken fragments of stalagmite, limestone, and gravel. There were found in this bed a human lower jaw-bone and various small bones. The third bed, the thickness of which has not been ascertained, consists of a stiff yellow clay containing large pebbles, some of which had evidently been used as hammers, two of them being pointed at one end. In this bed there was also found a portion of the antler of a stag measuring more than 3 feet in length.

It is evident that from the earliest times this cave has been the habitation of man and various wild animals, and it is proposed at the beginning of spring to make a systematic exploration, when no doubt many more objects of interest will be found. Young Mr. Millett wrote to Professor Boyd Dawkins acquainting him with his discoveries, and the Professor very kindly offered to name the specimens. The young cave-hunter continues his explorations, and gives all his spare time to the work of seeking for objects of scientific interest in various parts of the cave, and especially in the stalagmitic substance in which some of the animal remains have been embedded.

The following is a list of fauna, the bones of which have been found in the caves of Derbyshire:—the woolly rhinoceros (*Rhinoceros tichorhinus*), found at Castleton, Wirksworth and Creswell; the Irish elk (*Cervus megaceros*), at Creswell; the grisly bear (*Ursus ferox*), at Castleton and Creswell; the glutton (*Gulo luscus*), at Creswell; the leopard (*Felis pardus*), at

Creswell; the cave lion (*Felis spelæa*), at Creswell; the wild boar (*Sus scrofa*), at Creswell, Castleton, and Deep Dale; the reindeer (*Cervus tarandus*), at Wirksworth, Castleton, Creswell, Bradewell, and Deep Dale; the roebuck (*Cervus capreolus*), at Castleton and Pleasley; the bison (*Bos priscus*), at Castleton and Creswell; the mammoth (*Elephas primigenius*) at Creswell, Dove Holes, and Castleton; the red deer (*Cervus elaphus*), at Castleton, Bakewell, Lathhill, Wirksworth, and Deep Dale; the brown bear (*Ursus arctos*), at Deep Dale and Monsal Dale; the lynx (*Felis lynx*), at Pleasley; the fox (*Canis vulpis*), at Castleton; the cave hyæna (*Hyæna spelæa*), at Creswell; the woolly hyæna (*Canis lupus*), at Castleton and Creswell; the horse (*Equus caballus*) at Deep Dale, Creswell, and Wirksworth; the wild cat (*Felis catus*), at Creswell; the hippopotamus (*Hippopotamus major*), at Mother Grundy's Parlour; and the ox (*Bos longifrons*) at Wirksworth and Deep Dale.

NOTES ON AN EXAMINATION OF A FEW ANGLESEY ROCKS.

By P. Holland, F.C.S., F.I.C., and E. Dickson, F.G.S.

Mr. Mellard Reade, in his paper on the excursion of the Society to Anglesey in Easter, 1889, read before the Society in the early part of this present session, referred to the instances met with where the slates and schists were interpenetrated by igneous intrusions, in one case nine distinct layers or sheets of such igneous intrusions being counted in as many inches. It occurred to us that it would be interesting to examine chemically and microscopically a few cases where this contact occurred; and

although, owing to the very considerable length of time necessary for the proper examination of each specimen, we have not been able to examine many of these cases, still the few we have examined have given interesting results. In the 58th volume of the Reports of the British Association there is a valuable report, drawn up by Professor Blake, on the microscopic structure of some of the older rocks of Anglesey; but this report does not (as far as we are aware) deal with cases where rocks of a slaty or schistose character have been altered by contact with igneous rocks.

The first specimens were collected in Borth Bay, on the north-west coast of Anglesey, where—as mentioned by Mr. Reade in his paper—the slate was traversed by so many layers of igneous intrusions. These intrusions varied in width from about half an inch (or even less) upwards.

A piece of slate from the rock on the shore of the Bay was collected at a distance of ten inches below an intrusive sheet of about three or four inches in width, and examined chemically and microscopically. The microscopic and macroscopic examination showed it to resemble an ordinary sample of Killas, and it is noteworthy that the igneous intrusion had not affected the rock, though only ten inches removed from it.

The chemical examination of this same specimen gave the following result:—

Silica	70·58
Alumina	13·23
Peroxide of Iron	4·23
Protoxide of Iron	1·24
Manganese Oxide	0·35
Titanic Oxide	0·62
Phosphoric Acid	trace
Lime	—

Magnesia	1·83
Potash	1·92
Soda	3·52
Combined Water	2·18
	99·74
Specific gravity	2·72

The chemical analysis appears thus to bear out the microscopical examination, as the analysis is that of an average slate: if anything, the silica is slightly above, and the alumina slightly below, the average amount in a slate of the older geological series.

The igneous intrusion itself was next examined, and a microscopic section submitted to Mr. Rutley, who says with regard to it "that it consists of micro-crystalline "felsitic matter of extremely fine texture, through which "run some more coarsely crystallised strings and veins, "consisting, in his opinion, principally of quartz grains, "some of which may be in a position of strain."

The microscopic examination is corroborated by the chemical analysis of the rock, which is as follows. (In making the analysis the igneous intrusive matter was first carefully separated from the slaty matter.)—

19.	Silica	82·48
	Alumina	9·48
	Peroxide of Iron	0·63
	Protoxide of Iron	0·74
	Manganese Oxide	0·83
	Titanic Oxide	—
	Phosphoric Acid	—
	Lime	—
	Magnesia	1·11
	Potash	1·13
	Soda	2·01
	Combined Water	1·72
		100·13
	Specific gravity	2·60

As might have been expected, the slate where in contact with the igneous intrusion had undergone very considerable change, having assumed a talcose appearance. Unfortunately the amount of the altered slate was too small to allow of a chemical examination being made, and it was only with considerable difficulty that a slide could be obtained of the altered slate, and an examination of the slide does not give any very definite information. In Mr. Rutley's opinion, at the point of contact this fine micro-crystalline material appears to be mixed with a substance which he thinks is possibly talc. This mixed material forms irregular wavy bands, at times containing aggregates of small pale greenish scales, apparently chlorite, and little opaque more or less lenticular streaks, which lie parallel to the general direction of the banding of the rock. In this case we would thus appear to have a transition from a clay to a chlorite slate as the result of contact with the intrusive mass.

The next three specimens examined were collected from the rock on the side of a small bay, called Porth-y-Gwartheg, which lies to the west of Camlyn Bay, on the north-west coast of the island. Here an intrusive sheet had penetrated the slate, and there were exhibited most clearly and beautifully instances of (1) unaltered slate, (2) mixture of intrusion and slate, (3) unmixed intrusive rock, the whole occurring within a distance of about two feet. We thought that it would be interesting to examine a specimen of each.

The examination of (3) the intrusive rock gave the following result:—

88A.	Silica	65·03
	Alumina	17·76
	Peroxide of Iron	2·55

Protoxide of Iron	1·36
Manganese Oxide	0·24
Titanic Oxide	0·86
Phosphoric Acid	a trace
Lime	0·98
Magnesia	2·73
Potash	2·76
Soda	2·50
Combined Water	3·16
	99·92
Specific gravity	2·64

Comparing this with the intrusive rock previously examined, it will be noticed that this rock contains 17 per cent. less silica, but 8 per cent. more alumina.

Mr. Rutley's opinion on a microscopic examination of the rock is that it consists of numerous irregularly shaped grains of quartz, felspar, and magnetite, with a considerable amount of felsitic matter, and some decomposed felspar. The structure is that of a rock which has undergone mechanical deformation. An examination of (2) the intermediate rock gave the following result:—

33.	Silica	65·32
	Alumina..	16·62
	Peroxide of Iron	6·68
	Protoxide of Iron	1·05
	Manganese Oxide	0·27
	Titanic Oxide	0·70
	Phosphoric Acid	0·13
	Lime	1·10
	Magnesia	1·12
	Potash	3·25
	Soda	1·46
	Combined Water	2·18
		99·03
	Specific gravity	2·65

closely thus resembling 33A.

Mr. Rutley's opinion with regard to this rock is that it is a highly crushed rock, and heavily charged with ferric oxide, to which it owes its deep red colour. A considerable portion of the section consists of strings and veins of felsitic matter. The structure of the rock is exactly such as would result from a shearing movement. Although not detected in the slide it is probable that apatite occurs, judging from the presence of phosphoric acid in the analysis. The third specimen of this trio (1) was taken from the top, about 2 ft. from the dyke, and on analysis, gave the following result:—

33c.	Silica	70·74
	Alumina	12·79
	Peroxide of Iron	4·76
	Protoxide of Iron	1·26
	Manganese Oxide	0·38
	Titanic Oxide	0·41
	Phosphoric Acid	—
	Lime	trace.
	Magnesia	2·97
	Potash	1·90
	Soda	2·35
	Combined Water	2·61
		100·17
	Specific gravity	2·65

On being examined microscopically a section presented all the appearance of a crushed and apparently sheared slaty rock, traversed by veins of quartz and felspar. The finely triturated nature of the rock, and the decomposed condition of the component grains, render the precise determination of the minerals difficult. On *one* side, the section passes into ordinary slate. The above three sections appear to represent different phases of the mechanical deformation and chemical alteration of a somewhat similar rock.

Mr. Reade referred in his paper to the Cemmaes Limestone, which occurs on the N. coast of the island.

The limestone is unfossiliferous, and a chemical origin has been ascribed to it. The rock is described in the Report on the Anglesey Rocks in the 58th Vol. of the Reports of the British Association. It appears to be a finely crystalline, slightly magnesian limestone, traversed by veins of calcite.

Mr. Rutley noticed in the section small, dark, opaque flecks and streaks, which he thought might represent the carbonaceous matter in the analysis.

A chemical analysis of this rock gave the following result:

Carbonate of Lime	96·560
Carbonate of Magnesia	0·776
Phosphate of Lime	0·091
Alumina	0·040
Peroxide of Iron	0 076
Protoxide of Iron	0·182
Manganese Oxide	trace.
Titanic Oxide	—
Silica	1·650
Potash	0·069
Soda	0·016
Carbonaceous matter	0·228
Combined Water	2·270
	99·948
Specific gravity	2·61

The analysis is interesting, as this rock is usually classed as a magnesian limestone.

The presence of the carbonaceous matter is also important, and may help to throw light upon the origin of this limestone.

It may perhaps not be out of place to mention that the plan of analysing the rocks forming the subject of

this communication was, except in the case of the Cemmaes limestone, the one described in the *Chemical News* of January 18th, 1889. For estimating the alkalies the lime fusion plan of L. Smith was used, and after weighing the alkaline chlorides so obtained the potash was separated as platinum salt in the usual way As regards the water of combination 4 grains or so of the finely powdered rock were taken and strongly heated in a current of dry air, the moisture being collected in a previously weighed chloride of calcium tube. The ferrous iron was found by digesting in a sealed tube at 133° C. with pure HCl not less than 3 grains of the sample. The suitably diluted solution of the iron was subsequently treated with potassium dichromate. In estimating the alkalies in the Cemmaes limestone 10 grains were taken, and half that weight for the phosphoric acid, which was separated by the Molybdate method, and finally weighed as magnesian pyrophosphate. Platinum dishes were used to the exclusion of glass and porcelain for all evaporations and concentrations of filtrates.

NOTE ON SOME MAMMALIAN BONES FOUND IN THE BLUE CLAY BELOW THE PEAT-AND-FOREST BED AT THE ALT MOUTH.

By T. Mellard Reade, C.E., F.G.S.

These remains, determined and detailed below by Mr. T. J. Moore, Corr. M. Z.S.L., were taken out of the blue clay (Formby and Leasowe marine beds) immediately below the Peat and Forest Bed by my son Aleyn and myself. The special interest of the two finds lies in

the fact of the remains being undoubtedly *in situ*. Most of the bones found on former occasions, some of which have been noted in the Society's proceedings, having been washed out of the beds and deposited on the shore, it has been impossible to say positively from what stratum they came. A great number of my former finds are now in the Museum, William Brown Street, Liverpool.

LIST OF BONES DETERMINED BY MR. T. J. MOORE.

1 Right Tibia of Red Deer—14 in. long.

1 Metatarsus of Red Deer—13½ in. restored.

1 Right Femur of Red Deer—10⅜ in. long.

1 Right Acetabular region of hip bone, of Red Deer, ends broken off—7 in. long.

1 Astragulus of Red Deer }
1 Calcaneum of Red Deer } Fit one another.

The above were found April 14th, 1889, embedded in blue clay under the peat 150 yards N. of Thornbeck Pool.

1 Humerus of Horse—12 in. long. Taken from blue silt immediately under two feet of Peat-and-Forest bed, Alt Mouth, south of Thornbeck Pool, Nov., 1886.

Upper portion of Right Tibia of Horse—7 in. long.

"The bones of the Red Deer are probably those of one and the same animal, and I think are moderate in size, though larger than those of our specimens, which are young."

FIELD MEETING AT THE BARTON SECTION OF THE SHIP CANAL, MAY 25TH, 1889.

The party first examined the cutting above Barton aqueduct, where the Pebble Beds were exposed. The beds were of the usual character, but some pebbles of volcanic rocks attracted attention as being unusual in the district. Near the present course of the river a thick series of gravels rest upon a surface of sandstone, which showed numerous evidences of river erosion, such as grooves and rounded ridges and occasional deep pot-holes or mills. The solid geology rises from a point about 30 yards from the river, and the old fluviatile deposits were seen to abut against a beetling bank of sandstone. This bank is traceable by the surface contours for a considerable distance in a series of sweeping bays.

The next cutting to be visited was that called "Salt Eye Cutting," and it exhibited a very fine series of beds. At the end nearest to Barton the Upper Mottled Sandstone was exposed, but its surface fell rapidly to the westward, where it was covered with Boulder Clay and that in its turn by coarse river gravels containing a great number of large tree trunks. The gravel was overlaid by a fairly clean sandy silt, which gradually thickened towards the westward with a concurrent fall of the surface of the gravel until the latter deposit disappeared below the floor of the cutting. The silt led to some speculation, as it presented peculiarities of oblique-bedding which, coupled with the fact that roots of grasses and other herbs penetrated every layer, looked very much like the arrangement of blown sand; however, a fortuitous patch of silt upon the actual river-bank showed precisely the same characteristics. The place was inspected where the canoe, which is now at the Owens' College, was found embedded in the lower part of the silt, and the members then proceeded to the next—Sticking's Island cutting, where a silt was found similar to that at Salt Eye, though dipping in the opposite direction, *i.e.*, towards the E., and of much less thickness.

In this silt a comb of doubtful antiquity had been found, and the members dug out several pieces of leather from the same horizon. A little further on an old well buried in silt was inspected, but no definite opinion was expressed as to its age or object, except that it was very modern.

At about the middle of the length of the cutting attention was directed to the surface of sandstone which has been described as showing glacial scratches, and members were invited to bear testimony

to the fact that it was merely such furrowing as rivers commonly effect, and certainly had no features in common with glacial markings.

At the eastern end of the cutting, the Upper Mottled Sandstone was well seen in the excavation for the locks. Adjacent to this spot a small patch of Peat was seen resting against Boulder Clay. A great number of boulders varying in weight from small pebbles up to blocks weighing a ton or more were scattered about the cutting, and amongst them good examples of all the typical erratics were noticed, including the Buttermere Granophyre, Eskdale Granite, Yewdale Agglomerate, and —what was looked upon as eminently characteristic of the particular district—a block of Permian Limestone containing *Bakevellia antiqua*, and *Pleurophorus costatus*.

P. F. KENDALL.

FIELD MEETING AT BURTON POINT, JULY 20TH, 1889.

The object of this excursion was to enable the members to examine the fine section of the Middle Bunter exposed at Burton Point. Driving from Neston, we left the conveyance at the place where the road from Burton village reaches the shore. About a hundred yards or so from this the northern or upper end of the section is reached, and consists of a series of thin bedded sandstones, at times much contorted and also weathered. They contain a few quartzite, &c., pebbles sparsely scattered through them. Passing southwards pebbles become more frequent, and a little further along the stone has been quarried, leaving a clean face and continuous section some 20 feet high and of considerable length and more or less in the direction of the dip, so as to shew clearly the successive beds. Bands of pebbles are then met with, coming nearer and nearer together till it becomes a continuous conglomerate, only broken near the base by a few thin bands of yellowish shale. Just at the point a bed of yellow shale, about 1 ft. 6 in. to 2 ft. thick, is seen, and below it the brilliant red and softer rock of the Lower Bunter quite free from pebbles, which may be followed some distance further along the shore, which here tends more to the eastward.

Leaving the water side we drove to the village, in the upper part of which several of the cottages are picturesquely perched on ledges of the conglomerate overhanging the softer Lower Bunter below.

H. C. BEASLEY.

MEMBERS
OF THE
LIVERPOOL GEOLOGICAL SOCIETY.

HONORARY MEMBERS.

WILLIAM BRYHAM, Wigan.
CHAS. CALLAWAY, D.Sc., F.G.S., Wellington, Salop.
ARCHIBALD GEIKIE, D.Sc., F.R.S., London.
HENRY HICKS, F.G.S., M.R.C.S.E., London.
JOHN W. JUDD, F.R.S., F.G.S., London.
*DANIEL MACINTOSH, F.G.S., 32, Glover Street, Birkenhead.
WILLIAM PENGELLY, F.R.S., F.G.S., Torquay.
SIR A. C. RAMSAY, F.R.S., F.G.S., London.

FOREIGN CORRESPONDING MEMBERS.

M. A. DAUBRÉE, Museum of Natural History, Paris.
DR. A. HEIM, University of Zurich.
MAJOR-GEN. N. VON KOKSCHAROW, Inst. of Mines, St. Petersburg.
PROF. J. VILANOVA-Y-PIERA, University of Madrid.
DR. A. F. RENARD, Museum of Natural History, Brussels.
BARON F. VON RICHTHOFEN, Berlin.
PROF. J. J. STEVENSON, University of New York.

MEMBERS.

*ARCHER F., B.A., 14, Cook Street.
*†BEASLEY, H. C., Prince Alfred Road, Wavertree.
*BROWN, J. CAMPBELL, Prof., D.Sc., F.C.S., 27, Abercromby Square.
CHALMERS, F. R., 54, Park Road South, Birkenhead.
CLAGUE, D., F.G.S., 81, Lime Grove.
*CUMMING, L., M.A., 14, Bilton Road, Rugby.
DAVIES, D., 55, Berkley Street.
DAVIS, T. H., F.I.C., 14, Imperial Chambers, Dale Street.
*DICKSON, E., F.G.S., 30, Eastbourne Road West, Birkdale.
*†ESKRIGGE, R. A., F.G.S., The Woodlands, New Brighton.
18, Hackins Hey.
FITZPATRICK, M., 62, Seel Street.
*FITZPATRICK, J. J., 62, Seel Street.
FOSTER, E., 41, Arundel Avenue, Sefton Park.
*GEORGE, I. E., 16, Wynnstay Street.
GOFFEY, T., Nicholas Road, Blundellsands.
GOODALL, W., 43, Walmer Road, Birkdale.

HANCE, E. M., LL.B. *(Hon. Treasurer)*, Municipal Offices, Dale Street.
*HERDMAN, W. A., Prof., D.Sc., F.R.S.E., University College.
*HIGGINS, Rev. H. H., M.A., 29, Falkner Square.
HILL, H. ASHTON, C.E., Wallasey Gas and Water Works, Liscard.
*HEWITT, W., B.Sc. *(Hon. Secretary)*, 16, Clarence Road, Birkenhead.
*HOLLAND, P., F.C.S., 26, Talbot Street, Southport.
JACKSON, G. O., 5, Coltart Road.
*JEFFS, O. W., 12, Queen's Road, Rock Ferry.
KELLY, J. DUNBAR, 4, Sweeting Street.
KENNARD, J., F.R.G.S, 39, Thompson Street, Birkenhead.
KEYTE, T. S., C.E., 9, Chatham Place.
KNIGHT, A. H., F.C.S., 22, Radnor Place, Claughton.
LINDSAY, R. C., B.Sc., 112, Anfield Road.
*LOMAS J., 23, Avondale Road.
MOORE, C. C., 125, Chester Road, Hartford, Northwich.
*MARRAT, F. P., 13, Nursery Lane, Broad Green.
MILES, C. E., 57, Willow Bank Road, Tranmere.
MILES, W. H., 9, The Woodlands, Birkenhead.
*MOORE, T. J., C.M.Z.S.L., 14, Gardner Road, West Derby.
Liverpool Museum.
MORTIMER, Captain, Liverpool.
*†MORTON, G. H., F.G.S., F.R.G.S.I., 209, Edge Lane.
NEWALL, E., 14, Elm Grove, Tranmere.
PATERSON, J., C.E., F.G.S., Palmyra Street, Warrington.
PALMER, S. J., M.B., M.R.C.S., Netherfield Hospital.
*POTTER, C., 101, Miles Street.
*†READE, T. M., C.E., F.G.S., Park Corner, Blundellsands.
Canning Chambers, South John Street.
*†RICKETTS, C., M.D., F.G.S., 18, Hamilton Square, Birkenhead.
*†ROBERTS, I., F.G.S., Kennessee, Maghull.
RICHARDSON, W. A., C.E., Valley Lodge, Borough Road, Birkenhead.
ROBINSON, J. J., 36, York Road, Birkdale.
*SEMMONS, W., The Priory, Higher Broughton, Manchester.
SHONE, W., F.G.S., Upton Park, Chester.
*TATE, A. NORMAN, F.I.C., F.C.S., F.G.S., 9, Hackins Hey.
*TIMMINS, A., C.E., Argyll Villa, Runcorn.
TUNSTALL, J., 45, Vine Street.
TWEMLOW, J., 1, May Street.
*WARD, T., Brookfield House, Northwich.

ASSOCIATES.

MORTON, Miss S. E., 209, Edge Lane.
READE, Mrs., Park Corner, Blundellsands.

* Have read Papers before the Society.
† Contribute annually to the Printing Fund.

CONTENTS.

PROCEEDINGS

OF THE

Liverpool Geological Society.

SESSION THE THIRTY-SECOND,

1890-91.

EDITED BY H. C. BEASLEY.

(*The Authors, having revised their own Papers, are alone responsible for the facts and opinions expressed in them.*

PART 3. VOL. VI.

LIVERPOOL:
C. TINLING AND CO., PRINTERS, VICTORIA STREET.

1891.

PROCEEDINGS

OF THE

Liverpool Geological Society.

SESSION THE THIRTY-SECOND,

1890-91.

EDITED BY H. C. BEASLEY.

(The Authors, having revised their own Papers, are alone responsible for the facts and opinions expressed in them.

PART 3. VOL. VI.

LIVERPOOL:
C. TINLING AND CO., PRINTERS, VICTORIA STREET.

1891.

OFFICERS 1890-91.

President:

W. HEWITT, B.Sc.

Ex-President:

C. RICKETTS, M.D., F.G.S.

Vice-President:

E. DICKSON, F.G.S.

Hon. Treasurer:

E. M. HANCE, LL B.

Hon. Librarian:

J. J. FITZPATRICK.

Hon. Secretary:

H. C. BEASLEY.

Council:

D. DAVIES.
J. LOMAS, Assoc. N.S.S.
W. H. MILES.
G. H. MORTON, F.G.S.
T MELLARD READE, C.E., F.G.S.

LIST OF SOCIETIES, ETC., TO WHICH THE PROCEEDINGS OF THE LIVERPOOL GEOLOGICAL SOCIETY ARE SENT.

(Publications have been received in exchange during the Session from those marked)*

*Academy of Natural Sciences, Philadelphia.
Advocates' Library, Edinburgh.
*Australian Museum, Sydney.
*Belfast Naturalists' Field Club.
*Birkenhead Free Public Library
* ,, Literary and Scientific Society.
Birmingham Philosophical Society.
Bootle Free Public Library.
British Museum.
British Museum (Natural History) Geological Department.
*British Association for the Advancement of Science.
*Bristol Naturalists' Society.
Bodleian Library, Oxford.
*Boston Society of Natural History, U.S.
*Chester Society of Natural Science.
*Colorado Scientific Society.
Dudley and Midland Geological and Scientific Society.
*Essex Naturalists' Field Club.
Editor of "Geological Record."
,, "Nature."
,, "Geological Magazine."
,, Science Gossip."
Ertborn, Le Baron O. Van, Anvers, Belgique.
*Geological Society of Edinburgh.
Geological Society of Glasgow.
*Geological Society of London.
*Geological Society of Manchester.
Geological Society of Norwich.
*Geological Society of Australasia, Melbourne.
*Geological Survey of the United States.
Geological Survey of India.
*Geological Survey of Canada.
*Geological Survey of Missouri.
*Geologists' Association, London.
*Glasgow Philosophical Society.
Hungarian Karpathian Society, Locse.

*Imperial Academy of Naturalists, Halle, Prussia.
*Kansas Academy of Sciences, Topeka.
*Leeds Philosophical and Literary Society.
Leeds Geological Association.
Liverpool Athenæum.
,, Chemists' Association.
* ,, Free Public Library.
* ,, Geological Association.
* ,, Literary and Philosophical Society.
,, Lyceum Library.
,, Philomathic Society.
* ,, Engineering Society.
* ,, Astronomical Society.
* ,, Science Students' Association.
*L'Université Royal de Norvége, Christiana.
*Manchester Association of Engineers.
*Manchester Literary and Philosophical Society.
*Minnesota Academy of Natural Science, Minneapolis, U.S.
Musée Royal d'Histoire Naturelle de Belgique.
Museu Nacional, Rio de Janeiro.
Museum of Practical Geology, Jermyn Street, London.
*North of England Institute of Mining and Mechanical Engineers.
*New York Academy of Sciences.
Owens College, Manchester.
Patent Office Library, 25, Southampton Building, Chancery Lane, London, W.C.
*Rochester N.Y. Academy of Science.
*Royal Dublin Society.
Royal Geological Society of Ireland, Dublin.
Royal Society, London.
*Smithsonian Institution, Washington, U.S.
*Société Geologique de Belgique, Liege.
*Société Geologique du Nord, Lille.
*Société Impériale des Naturalistes de Moscow.
*Société Royale Malacologique de Belgique.
*Sociedade de Geografia de Lisbon.
*Toscana Societa di Scienza Naturali.
*University Library, Cambridge.
University College, Bangor.
,, ,, Liverpool.
*Warwickshire Natural History and Archæological Society.
Watford Natural History Society.
*Wagner Free Institute of Science, Philadelphia.
Woodwardian Museum, Cambridge.
Yorkshire Geological and Polytechnic Society.

PROCEEDINGS

OF THE

LIVERPOOL GEOLOGICAL SOCIETY.

SESSION THIRTY-SECOND.

OCTOBER 14TH, 1890.

THE PRESIDENT, DR. C. RICKETTS, F.G.S., in the Chair.

Mr. A. LUTSCHAUNIG was elected an Ordinary Member.

The Hon. Treasurer submitted his Statement of Accounts.

The Officers and Council for the ensuing year were elected.

The President read his ANNUAL ADDRESS.

NOVEMBER 11TH, 1890.

THE PRESIDENT, W. HEWITT, B.Sc., in the Chair.

Mr. ALEX. GORDON, Mr. W. H. ROCK, and Mr. S. SLATER were elected Ordinary Members

The following Papers were read :—

ON THE BASE OF THE KEUPER IN WIRRAL.

By H. C. BEASLEY.

REPORT ON THE SOCIETY'S EXCURSION TO THE WARBURTON SECTION OF THE MANCHESTER SHIP CANAL, and SUBSEQUENT VISIT TO A SECTION OF THE PERMIAN AT LEVENSHULME.

By J. LOMAS.

DECEMBER 9th, 1890.

The President, W. HEWITT, B.Sc., in the Chair.

Dr. H. W. Plant was elected an Ordinary Member.

The following Paper was read:—

NOTES ON MORAINES AND GLACIER STREAMS IN THE VALLEY OF THE RHONE, AND NEAR GRINDELWALD.

By E. Dickson, F.G.S.

JANUARY 14th, 1891.

The President, W. HEWITT, B.Sc., in the Chair.

The following Paper was read:—

THE TRIASSIC ROCKS OF THE VALE OF CLWYD.

By T. Mellard Reade, C.E., F.G.S.

FEBRUARY 10th, 1891.

The President, W. HEWITT, B.Sc., in the Chair.

The following Papers were read:—

REPORT ON THE FIELD MEETING OF THE SOCIETY AT A SECTION OF THE MIDDLE COAL MEASURES BETWEEN GARSWOOD AND ST. HELENS.

By J. J. Fitzpatrick.

THE PRINCIPAL FAULTED AREAS IN THE COUNTRY ROUND LIVERPOOL.

By G. H. Morton, F.G.S.

LIST OF PAPERS ON LOCAL GEOLOGY SINCE 1881.

By G. H. Morton, F.G.S.

MARCH 10TH, 1891.

THE PRESIDENT, W. HEWITT, B.Sc., in the Chair.

The following Paper was read :—

NOTES ON A SECTION OF THE TRIAS AND BOULDER CLAY IN CHAPEL STREET, LIVERPOOL.

By T. MELLARD READE, C.E., F.G.S.

APRIL 14TH, 1891.

THE PRESIDENT, W. HEWITT, B.Sc., in the Chair.

The following Papers were read :—

THE EXAMINATION OF THE WATER AND DEPOSITS OF GLACIAL STREAMS NEAR GRINDELWALD AND CHAMOUNY AND IN THE RHONE VALLEY.

By E. DICKSON F.G.S., and P. HOLLAND, F.C.S.

A FURTHER NOTE ON THE DECOMPOSED BOULDER AND UNDERLYING RED SANDSTONE IN THE CHAPEL STREET SECTION, LIVERPOOL.

By T. MELLARD READE, C.E., F.G.S.

FIELD MEETINGS were held during 1890, at—

Leicester and the neighbourhood.

Warburton Section of Manchester Ship Canal and Railway Cutting, near Levenshulme.

Garswood.

Warrington and Acton Grange Section of Manchester Ship Canal.

Frodsham.

Skipton and Bolton Abbey.

THE LIVERPOOL GEOLOGICAL SOCIETY,

E. M. HANCE, Hon. Treasurer, *in Account with the* Liverpool Geological Society, *Session* 1889-90.

	£	s.	d.
To Balance in hand, 7th Oct., 1889......	14	14	6
,, Subscriptions for current Session ...	34	7	6
,, Arrears from previous Sessions	7	11	6
,, Special donations to Library	0	7	6
,, Sale of Proceedings	1	5	0
	£58	6	0
To Balance in hand	£11	1	1

	£	s.	d.
By Geological Magazine, 2 years	1	16	0
,, ,, Record, 2 vols.	I	2	0
,, Palæontographical Society............	1	1	0
,, Hon. Secretary's Expenses, Session 1888-89..............	3	1	4
,, ,, Session 1889-80 ...	2	12	4
,, Hon. Librarian's Expenses...........	0	13	2
,, Hon. Treasurer's ,, ...	0	2	8
,, Rent—2 years, to 4th Oct., 1890 ...	10	0	0
,, Tinling & Co.—Printing	20	0	0
,, E. Doling, Session 1888-89...........	6	9	0
,, Excursion Expenses....................	0	7	5
,, Balance in hand	11	1	1
	£58	6	0

Audited and found correct,

(Signed) F. R. Chalmers.
J. Lomas.

PRESIDENT'S ADDRESS.

SOME PHENOMENA WHICH OCCURRED DURING THE GLACIAL EPOCH.

By Charles Ricketts, M.D., F.G.S.

A time honoured custom of our Society imposes on me the onerous duty of providing a subject for consideration at the opening of the Session. This can only be done satisfactorily by utilizing some topic to which my own attention has been specially directed, even though rendering it necessary to reconsider evidences, which, at different intervals, have been submitted to your notice, and, again produced, may be considered like unto "a twice told tale."

The subjects I have chosen are certain phenomena which occurred during what is known as the *Glacial Epoch.* Though so much has been written respecting this remarkable episode in the world's history, there are circumstances which have not been generally recognised, and others which appear wrongly interpreted; not infrequently theories have been advanced and accepted as if they represented facts which had been proved; instead of being used as a means of discovering the truth, by searching in other places for phenomena similar to those by which they were suggested, and comparing them together.

I quote Professor James Geikie in saying that "some of the extreme theories advanced by early investigators have been abandoned." One of them is that of a great polar ice-cap of sufficient thickness and extent to cause displacement of the Earth's centre of gravity, presumed to have extended from the North Pole as far south as to

latitude 55° N. There is an objection to this suggestion of a polar ice-cap which always appeared insuperable. If the British Isles and the greater part of Europe were covered with a mantle of perpetual snow, and if it existed in America as far south as the latitude of New York, the air passing over a land surface of such extent having a glacial temperature, must have had almost the whole of its water condensed out of it long before reaching the Arctic circle; to use an expression of the author of "Frost and Fire" (the late Mr. J. F. Campbell, F.G.S.) "the wet would be squeezed out by the cold, as water is wrung from a sponge." Under present conditions, according to Captain McClure, and confirmed by other Arctic explorers, "It is only here and there in dark and sunless ravines of North Devon, and Melville Island, a pigmy glacier may be found, but it never reaches the sea so as to form icebergs." Professor Nordenskiöld during his journey up the Yenissei (late in August) saw snow only at one place, in a cleft some fathoms in breadth, whilst the vegetation was distinguished by a luxuriance to which he had seldom seen anything comparable.* In territories lying to the north of the Arctic circle, there are to be found the most extensive and the finest forests on the globe.† According to Lieut. Peyer, of the Austrian Arctic Expedition, "Icebergs have never been seen on the coasts of Siberia, for no Glaciers exist there."‡

It is reasonable to suppose that, when Britain was covered with perennial snow, there would in the extreme north have been a deficiency of snow covering the ground, and the climate would have been greatly modified. During summer, the rays of the sun might

*The Arctic Voyages of Adolf Eric Nordenskiöld, p. 299.

† page 300.

‡ New Lands within the Arctic Circle, Vol. i., page 17.

have fallen for a time during a portion of the twenty-four hours, not on snow as at present, but on the bare ground, with almost tropical intensity; this would render the climate at that season of the year very much warmer; (during Captain Nares' expedition, the thermometer exposed within the Arctic circle to the direct rays of the sun, registered 128° and 129° Fahr. on June 13th and 21st respectively);* whilst on the other hand the cold of winter would be greatly intensified, there being no vapour in the atmosphere to check radiation.

Though the hypothesis of a Polar icecap in the northern hemisphere is now discarded, the idea is still advocated that a glacier, having its origin in the mountains and hills of Scotland, Cumberland, and the North of Ireland, filled up the Irish Sea, and extended as solid ice into the Atlantic at the South of Ireland. Another hypothesis, still maintained, is the existence of a glacier, having its origin in Cumberland and Westmoreland, which filled the Bay of Liverpool, and without any recognised barrier on its western margin to direct its course, passed over and abraded the Isle of Anglesey, sculpturing and fashioning it into its present form. I have likewise at meetings of our Society heard it stated that the Mersey glacier was forced *up* the course of its valley, in direct opposition to gravity, no high ground existing from which the force which originated the supposed movement could have been derived.

There is one fact, but it is by no means the only one, which renders each of these conjectures entirely untenable; Flints, derived from the Chalk, exist sparsely scattered in the Boulder Clay of Lancashire and Cheshire. The nearest locality, and the only one from which they can

* Official Report of the recent Arctic expedition, by Captain Nares, R.N., age 91.

with any probability be supposed to have been derived is the North of Ireland; but with the alleged barrier of a solid glacier passing down St. George's Channel, or of one filling up the Bay of Liverpool, it would be quite impossible for a single Chalk-flint or other rock-fragment to cross over from Ireland, and be deposited in the Boulder Clay of this district. (Conditions affecting some of these flints individually will be referred to hereafter.)

The term Boulder Clay is often used by many, especially by Scotch Geologists, to designate a very different state of materials to what we are accustomed to refer it. They apply it not only to marine deposits, such as with us, but also to accumulations left on the recession of glaciers. The number of Moraine accumulations in Scotland, and in the Northern counties of England, and the extent of country over which they are spread, is most surprising; judging from the astonishment expressed when attention is directed to them the character of these collections does not appear to be generally recognised. When reference has been made to them by authors they are often disposed of by the application of such terms as Northern Drift, Glacial deposits, &c. Certainly many a moderate sized hill, and many a mound of solid rock, has been shaped by glaciers, but even a greater number of mounds and hills, similar in shape and quite as large, are easily recognised as of Moraine origin; they consist of rock fragments, often striated, and massed together without order; their composition varies, according to that of the valleys from the disintegration of which they have been derived. There are also some hillocks, composed partly of solid rock, on and against which a quantity of moraine debris rests.

The Boulder Clay covers an extensive district in our neighbourhood, as a reddish brown unstratified clay full of pebbles and boulders, which are often grooved and striated, or otherwise eroded; the rock-fragments vary in size from several feet in diameter to that of sand and grit, with here and there small fragments of marine shells, very seldom a perfect one. These erratics, generally derived from distant localities, are irregularly dispersed through the Clay.

The origin of this Boulder Clay, not only the rock-fragments, but also the *Clay* itself, has been attributed to the dropping of materials which have been carried by floating ice; nor am I certain whether some do not still hold this opinion. Our friend Mr. Daniel Mackintosh, referring to this subject, shows the great improbability of this hypothesis; he remarks that "the erratic stones were apparently brought by a cause distinct from that which produced the sandy and gritty part of the formation, and the same remark applies to the clay of which the formation mainly consists. Icebergs could not have brought the *whole* of the deposit, with its local grit, erratics, and clay; while icebergs, carrying both clay and erratic stones, and dropping them at intervals into the slowly accumulating local materials, would have left a deposit much less uniform in its character and structure".* It cannot be conceived possible that erratics of varied composition derived from innumerable localities, could have been developed in clay derived from the same areas as the pebbles themselves, and its composition be essentially similar over a large extent of country.

The rock surfaces, as a rule, where protected by a deposit of clay or by moraines, especially if the latter

* Quar. Jour., Geol. Soc., Vol. xxxiii.; Page 734.

are impervious to water, retain marks of ice-action, being smoothed, grooved and striated in parallel lines, coinciding with the course of the valley or otherwise having a direct relation to the contour of the ground. These striated surfaces have been attributed to the action of icebergs. I have met with no indications on rock surfaces attributable to the stranding of icebergs, for marks caused by them, on being moved by the ebb and flow of the tide, must have been most irregular, varying in every direction. Groups of boulders similar to each other in character, and situated on the same horizon are occasionally met with in the Boulder Clay, and may indicate that the ice-mass in which they floated remained for a short time stationary, during which period the pebbles and erratic blocks were being precipitated into the clay. Blocks of Boulder Clay some years ago were seen imbedded in the sands covering the bottom of the Happy Valley, Birkenhead, this may have been due to their having been ploughed up in the progress of a mass of ice, from which they subsequently dropped into these beds of sand.*

In close connection with, and in part covering, the striated surfaces, there are in this neighbourhood accumulations derived from disintegration of Triassic rocks; they occur as unstratified sand or as angular fragments of sandstone irregularly massed together, the insterstices being filled with sand, or as at Flaybrick Quarry, near Tollemache Road, with pipe clay. The whole of the materials have been derived from the sandstones and marls in their immediate vicinity, constituting moraines left behind by glaciers. With rare exceptions, no erratics are contained in them, though some may occasionally

* Erratics in the Boulder Clay of Cheshire, &c., by C. Ricketts, Quar. Jour. Geol. Soc., vol. xli., fig. 2, page 593.

be found lying immediately upon them. It very generally occurs that they are covered in succession with Boulder Clay.

Dr. Robert Brown, F.R.G.S., the Arctic traveller and explorer, states that "sub-glacial rivers pour out from beneath the glacier, whether it lies at the sea or in a valley, and in summer and in winter. These sub-glacial rivers are thickly loaded with mud from the grinding of the glacier on the infrajacent rocks. After the stream reaches the sea, it discolours the water for miles, finally depositing on the bottom a thick coating of impalpable powder."* This being the case with respect to the hard crystalline rocks of Greenland, how much greater, with a similar relative power, must have been the abrasion beneath glaciers, of the easily disintegrated sandstones and shales of our Triassic and Coal measure strata? To such a source the clay, but the clay only of the Boulder Clay must be attributed; sub-glacier streams having washed it forward as fine mud widely distributed over the then sea-bottom.

Besides the unstratified sands considered to be moraine accumulations formed at the termination or on the flanks of glaciers, there occur in many districts beneath the Boulder Clay stratified sands, often false bedded, extending along the sides of valleys to a moderate height above the rocky bed of a river or brook in a locality chiefly consisting of Triassic strata, from which the great bulk of these sands (the lower drift sand of Mr. Morton) have been derived.

Some years ago (about 1875) these sands were, at different intervals, well exposed in "Happy Valley," Birkenhead, a minor tributary of the Mersey. They lay

* Physics of Arctic Ice, Quar. Jour., Geol. Soc.; Vol. xxvi; page 681.

in the bottom of the valley, and extend only ashort distance up its sides. These loose sands were stratified and sometimes false-bedded ; some beds were entirely free from erratics, whilst they were contained in others. There also occurred, imbedded in them a few examples of marine shells, always in a very fragmentary condition. In no instance was there found a pebble which was striated, but their surfaces were more rounded than the generality of erratics in the Boulder Clay, probably in consequence of the friction to which they were subjected by moving sand carried along by a sub-glacier stream. As the striated surfaces on the flanks of the Valley indicate the previous presence of a glacier, it may be concluded that the stream, issuing from beneath it higher up the valley, would wash away the disintegrated rocks; the mud and finer particles carried onwards as clay would form the matrix of the Boulder Clay; whilst the heavier sands would remain where the force of the stream was not sufficient to move them forward.

The conditions displayed in this little model of a valley apply to similar loose and stratified sands occurring in districts through which larger rivers flow, and from the disintegration of the rocks forming the water slopes of their valleys the great bulk of the sands have been derived. Amongst localities, here referred to, may be mentioned a railway cutting between Walkden and Pendlebury, near Manchester, in progress five years ago; the valley of the Soar near Leicester; at Belfast; and at Knock, in County Down. In making the tunnel under the Mersey, though glacial deposits were found, it fortunately happened that they consisted of hard sandy Boulder Clay, with many erratics, causing no more engineering difficulty than the Triassic sandstone. But a very different state of things was met with in the exten-

sion to the Park Station; great difficulty and expense were incurred in consequence of the course chosen being in the loose sands, situated in the lower portion of a pre-glacial valley, which would have been avoided by carrying it along Claughton Road, in a ridge of Triassic rock, separating the area on which Birkenhead stands from Happy Valley, now called Borough Road.

Boulders and pebbles of all sizes—from that of the erratic, monstrous as to size, found near and now removed to Owens College, Manchester, to sand and grit—are abundant in the Boulder Clay. They have been generally derived from rocks differing entirely from any *in situ* in the neighbourhood, but can be referred to those of Cumberland and the south-west of Scotland, to Ireland and North Wales, that is to the border lands enclosing the Bay of Liverpool. Many are smoothed and polished, and bear upon their surface grooves and striæ universally attributed to the grinding action of glaciers or shore ice. They are considered to have been carried away by icebergs and icefloes from which on melting they have dropped into the clay at the places where they are now found. A large proportion of these erratics have their longest diameter in a more or less vertical position as if they had dropped into the clay from above. This is also the case on the Eastern coast (Whitby), where this position is probably more frequent than here, at all events it is more conspicuous, the more compact clay holding the pebbles firmly in place, whilst a portion of each stands out in relief in consequence of the clay being washed away around.

It has been mentioned already that Flints are occasionally found in the Boulder Clay. They are of various sizes, from small fragments up to at least 3½lbs.

in weight, and have been exposed to conditions varying from each other. Some have been affected by long exposure to the weather; in one form the fractured surfaces have a peculiar enamelled appearance, the same state is not uncommon in Hampshire gravel and has been observed on Flints in the Boulder Clay of the East of England, and in that of Co. Down and Co. Antrim. In many there has been but little if any change since their removal from the chalk matrix, for they still retain their original white coating, and where flakes have been split off, the fractures appear quite fresh. In some these fractured surfaces bear evidences of having been broken off by forcible pressure, many are chipped and crushed at the edges, whilst others have the angles rubbed and rounded without materially affecting the plane surfaces; nodular projections have also been exposed to this grinding and chipping action.

Taking into consideration the great probability that these flints were originally derived from the N.E. of Ireland, it is desirable to determine from the geological formation of that district the manner in which these different and special changes might have been produced under glacial conditions. Chalk flints differ so much in character from other rocks that it is to be expected the action upon them beneath glaciers must likewise have been different; one is that no examples of glacial striæ have been met with on them in Cheshire or Lancashire. Nor do any bear indications of having been rounded by being rolled on the sea shore, or in the current of a river. The chipping and grinding of the edges cannot be referred to movements occurring whilst resting on the Trias, for under such circumstances the angles alone could not have suffered without the split surfaces being also rubbed and roughened by friction against the sandstone.

In many instances the splitting of the flints and the chipping of their angles can be determined as being caused by forcible pressure. A condition in the Chalk formation may afford a sufficient explanation for this occurrence. The Chalk of Antrim is interstratified with a succession of many layers of flint, and these flints could hardly be forcibly removed from their matrix, and carried along, without coming in contact with others, the pressure against which beneath the glacier must necessarily split off fragments from one or both.

Though the occurrence of Flints in the Boulder Clay is rare, they are far more frequent than any fragments of limestone which can be referred to the Chalk formation. I have met with about twenty pieces, the largest not greater than a pullet's egg; most were procured from a heap of clay which had been excavated in making the continuation of the Mersey tunnel, beneath Beckwith Street, Birkenhead, in which were also found comparatively a considerable number (about 100) of flint fragments. It could not be expected that flints would be abundant in the Boulder Clay when it is considered that though the area over which the Chalk in the North of Ireland extends is very considerable, covering the whole of County Antrim, the amount exposed is small, forming the base only of escarpments, the whole being buried beneath a thick covering of Basalt; even in the neighbourhood of Belfast, in close proximity to the Chalk, they are not found to be very abundant in glacial deposits. It has also to be considered that they have been carried into the Bay of Liverpool by means of icebergs and floes, which ploughed their way by the force of the wind through closely packed ice.

Blocks of Granite and of Volcanic rocks which have become weathered throughout, even to disintegration and separation of their constituent particles (each granule maintaining its relative position), are too frequent and conspicuous to have at any time escaped notice; but without investigation it has always been taken for granted that this state was due to chemical action, since being deposited in the Boulder Clay, even though fragments of rocks of a similar kind may have been found near them unaltered.

Many years ago, when looking for Flints in the Boulder Clay—in other words, seeking for evidences to prove the correctness or incorrectness of a theory then lately advanced, and accepted by many, that a great glacier had filled up the Irish Sea; or that one had extended across the Bay of Liverpool from Cumberland to Anglesey—I accidentally came into possession of an erratic which seemed very remarkable, it consisted of Silurian sandstone, bearing no marks of glacial friction, but had been so shaped by some erosive agency that each bed was well displayed, the harder strata standing in relief, the softer forming hollows.* Stimulated by finding this specimen, a little searching proved the existence, in the Boulder Clay, of a considerable number of boulders, many bearing striæ, on which are indications of weathering, in forms varying in accordance with the structure of each rock-fragment and other causes, but differing from what occurs with us at the present time. The striæ were generally, but not always, formed prior to the weathering.

Pebbles of different kinds of rock have been split into fragments; in the generality of cases the fractured surfaces afford no indications of further weathering; in

---

* Proc. Liverpool Geological Society, Vol. iv, Page 17, fig. 3.

some the pieces remain in apposition, but others were detached and separated before their deposition in the Boulder Clay; instances have been met with where the distance between the fragments is so slight that they must necessarily have fallen at the same moment, it is presumed, from floating ice.*

Where there exist in the pebbles indications of varying hardness, or a hard infilling of joints, the softer material has been so removed that the more compact stands in relief; not unfrequently the disintegrated fragments remain *in situ* as a fine powder.

It seldom occurs that boulders of Carboniferous Limestone are weathered all over; some have been split into two or more pieces; but more remarkable, and also more frequent, is the formation of grooves or channels as if they had been gouged out, excepting that the organisms are standing in relief; this has occurred without materially affecting other parts which may bear upon them glacial striæ. Somewhat similar grooves have been observed even in rounded quartzite pebbles.†

These and other kinds of weathered erratics, existing in the Boulder Clay, have attracted very little attention, with the exception of those of Granite or Trap. The first to direct our notice to an example of them was our friend the late Robert Bostock. It was a block of Carboniferous Limestone, with its surface striated, and having a large groove or channel excavated in an irregular course. No cause was assigned for its peculiar condition, and the investigation extended no farther.

The question necessarily arose: from what cause, or under what circumstances have originated these remark-

---

**Op. cit.*, fig. 8; and Q. J.G.S.; vol xli, page 596, fig. 3.

†Proc. L'pool. G.S., vol. iv., page 17, fig 7

able forms of weathering, differing so greatly from any now happening? For a considerable time I took advantage of every opportunity of examining the weathering of rocks, under present conditions, and found none representing the peculiar effects occurring in the erratics referred to in the Boulder Clay. The thought then arose that each might have formed for a time part of a moraine on land, and had been exposed there to repeated successions of frost and thaw and other vicissitudes of weather, until subsequently an increase in the glacier carried forward the accumulation seaward, and as an iceberg floated with it away, dropping gradually, as the ice melted, its load of rock debris in the places where found. Holding this idea, the first mounds examined, containing striated pebbles, afforded specimens of some that were split, without displacement of the fragments; it occurred on the flanks of the Longmynd, and near Linley Hall, Shropshire. Subsequently, moraine heaps in other localities, afforded examples in abundance of weathering peculiar in the rocks affected according to their character. Some fragments of Granite and Trap are completely disintegrated without displacement of the particles; blocks of Silurian origin are split and eroded, displaying minutely every bed and joint. Instances of striated pebbles of Carboniferous Limestone are eroded and split, or have grooves and channels formed in them. All the examples are similar to, some the exact counterpart of others from the Boulder Clay. Where split pebbles of the different kinds of rock are met with in moraines, the fragments still remain in their relative position.

Though these boulders indicate alternations of climate at different seasons, and in different years, there is not sufficient evidence on which to found the hypothesis of an inter-glacial period, for these weathered boulders

exist at all levels and in all localities in the Boulder Clay.

The occurrence of masses of unconsolidated sands and gravels is frequent in the Boulder Clay, and they are often alluded to as 'pockets of sand,' &c. Their general form is lenticular, and their composition would lead to the inference that they have been derived from such sands as those previously alluded to, as occurring in the bottom of the valleys, and, like other erratics, have been conveyed by floating ice, from which they dropped on its melting; their shape being due to the falling away of the sand all round the mass, as it thawed and settled into the unconsolidated clay.

Vegetation, though very scanty during this period, was not entirely absent; several blocks of sand and clay have been met with, in two localities, containing a few erratic pebbles, as well as bands of vegetable mould. In some the clayey carbonaceous beds were doubled on themselves; the loose sand, which enveloped one of them, had fallen away in the manner previously alluded as occurring with masses of loose sand in the clay.

The only example of the occurrence of vegetation *in situ* on land was in a moraine, utilized as a gravel pit on the eastern side of Storr's Moss, three miles North-West of Carnforth, an accumulation of Carboniferous Limestone and Silurian pebbles was covered for about a foot in depth or thickness with a jet black carbonaceous powder, over which was spread a considerable amount of moraine debris.

Though all the Boulders have been conveyed to the Boulder Clay in floating ice, it would, I believe, in the majority of cases, be impossible to determine whether they had been brought by icebergs, or whether the markings upon them had been formed by shore ice, by

which pebbles are "rounded and scratched as distinctly as others taken from moraines."* Occasionally limestone pebbles are met with, the glaciation of which can, with almost absolute certainty, be referred to the action of shore ice. A few Carboniferous Limestone pebbles have had their substance perforated by mollusks, and other marine organisms, as well as being smoothed, striated, and split, subsequent to being bored by these animals. It is seldom that the shells remain in the cavities. Mr. T. Mellard Reade, during last session, exhibited a specimen with several; it was the best example of these borings I have seen; on one side it had the surface smoothed and striated. Amongst a number of specimens I only recollect finding a solitary instance in Carboniferous Limstone of a shell remaining in the cavity, another occurred in a softer limestone, in which were several shells entire, the surface being likewise covered with *Serpulæ*.† As the borings by these marine animals could only have occurred along the sea margin, the glaciation to which they have also been subjected must have been due to the action of ice along the shore, from which they have been conveyed in ice-floes.

A state almost universally affecting the Boulder Clay is its unstratified character, even though formed under circumstances which, had they occurred under present climatic conditions, would have been very favourable for the production of a stratified appearance. Deposited as fine mud, it has scattered in it an innumerable amount of erratic pebbles, a large proportion of which are of minute size, as of sand or grit. The base of the deposit was in this neighbourhood, and in other places situated at a

---

* "The Geology of the Arctic Coasts," by Captain H. W. Fielden and C. E. De Rance, Quar. Jour. Geol. Soc.; Vol. xxxiv., page 566.

† C. Ricketts, Q. J. G. S., Vol. xli., p. 595.

moderate depth below the sea-level therefore, if exposed to the action of waves and currents, it appears certain that the smallest of these rock fragments must have been arranged in lines, shewing evidences of stratification. This unstratified state is but another phase in the condition of the climate at the time. A consideration of what has been already stated shews that the sea must have been covered with ice-bergs and floes, conveying into the area the innumerable pebbles, &c., contained in the clay. This covering must necessarily have protected the sea from the action of the wind, so that no waves could have existed to cause such motion of the water as would have redistributed these fragments, not even those of sand and grit, whilst there would have been no great hindrance to the ice being impelled by the force of the wind on its exposed surfaces through the water. Under circumstances similiar to those here supposed, Lieut. Julius Peyer states that "however great the agitation of the sea may be in the open ocean, and though it may dash its waves with wild fury on the edge of the ice, within the ice girdle it is undisturbed."* In January, 1881, there occurred, at the time of low water, a heavy fall of snow, covering the sandbanks in the Upper Mersey to a considerable depth. On the return of the tide this was floated off, and gradually drifted downwards to the narrow part between Birkenhead and Liverpool, where it extended across the whole distance. Outside the snow the waves were rather considerable, but on reaching the ice they terminated in a swell for a short space, whilst, inside, the surface was perfectly unmoved. The effect of ice in keeping the sea smooth is well recognised by Arctic explorers.†

* "New Lands within the Arctic Circle," chap. 1, sec. 23.

† See Sir John Ross' Second Voyage in Search of a North-West Passage, 1829-33, page 83 and page 113.

There is another important question, one which, until lately, has been so entirely avoided by geologists as not to have been considered by them from a geological or physiographical point of view—What has caused this great change of climate, continuing for so long a period and occurring presumably at the same time over such extensive districts, and in different regions of the earth? The theories advanced, attributing its cause to astronomical changes, appear to have originated in the idea that the greater the intensity of cold or the less power the sun has in causing warmth upon the earth, so much the greater must be the snowfall in Arctic regions; a circumstance by no means coinciding with what is now observed there. Even in our own country it is not during the coldest winters we experience the greatest fall of snow and rain. Heat as well as cold is requisite before a district can be covered with perennial snow; it is necessary there should be heat in one place, to raise the watery vapour from the sea, before it can be precipitated on land as snow by the coldness of the atmosphere in another. "Without solar fire," says Tyndall, "we could have no atmospheric vapour, without vapour no clouds, without clouds no snow, and without snow no glaciers; * the lessening of the sun's heat would infallibly diminish the quantity of aqueous vapour, and thus cut off the glaciers at their source." In their formation "*heat* plays quite as necessary a part as *cold*, and before Bishop Heber could speak of 'Greenland's icy mountains,' the equatorial ocean had to be warmed by the sun."† Before handing over the question of the cause of the Glacial Period to be determined from the views of the astronomer, it behoved geologists to consider

* "Forms of Water." 6th Edit., page 7.

† *Op cit*, page 21.

whether any geological changes have taken place, or any might have occurred, by which such alterations of climate could have been induced. There is one condition, so far as I am aware accepted by all, that coldness of our climate would be greatly intensified by the removal of the Gulf Stream. Professor James Geikie states that "were it not for the genial influence of the Gulf Stream, Scotland would experience a climate as severe as that of Labrador, while the greater part of Norway would be uninhabitable."* Again, it was remarked by Dr. James Croll that "the stoppage of the Gulf Stream would place Europe under glacial conditions." † Yet endeavours have not been made to determine by what means this state could have been induced—whether any difference in the configuration of the land has taken place, which would render its occurrence, not only possible, but at some time probable. Previous to the Glacial Epoch, there was a time when such an alteration in the distribution of the land and water existed in North America that the climate in the extreme north must have been much milder than at present. During Tertiary times Florida was situated below the sea level, and a broad strip of where is now land, along the East Coast of North America, was then sea, so abounding in animal life that bones and other exuviæ, representative of the period, have been exported in great quantities for agricultural manures. Amongst these remains imported for this purpose, into Liverpool, are a very great number of teeth of various kinds of Shark, many of an enormous size; tusks of Whale, with *Ostrea* and other marine shells. I possess likewise, stated to have been derived from the same locality, an Elephant's molar tooth, a portion of horn of Deer, and Teeth somewhat comparable to those of Horse.

* "The Great Ice Age," page 112.
† "Climate and Time," page 70.

It is inferred that, if the barrier of land now forming the Isthmus of Panama then existed, but at the same there was no impediment as now to the flow northward of the warm water from the Gulf of Mexico in consequence of the absence of the Peninsula of Florida, especially when combined with a considerable belt of country on the east coast of the United States, the warm Equatorial water would pass unimpeded 350 miles northward of where it does at present, making really a difference of 700 miles, as it now has to traverse the extent of Florida twice. Such an occurrence might be sufficient to account for the luxuriant vegetation once flourishing in the now cold and barren country of Greenland.

On the other hand, let it be considered that subsidence, even to a comparatively moderate depth, has taken place in Central America, this would cause, according to the extent of the depression, a considerable quantity of the hottest, because the surface, waters of the Caribbean Sea to flow into the Pacific. The lowest summit of the dividing ridge between the two oceans is near Lake Nicaragua; this lake was calculated by Mr. John Baily (1849) to be 121 feet 9 inches above sea level.* The result of a survey by Colonel O. W. Childs (1851), made it 107 ft. 6 in.; the lowest pass between the lake and the Pacific is 26 feet above the lake; so that the elevation between the two oceans is, according to this estimate, only 133 feet.† The highest land traversed by the Panama Railway is 299 feet.‡ A route, surveyed and proposed by Lieut. L. N. B. Wyse, for a ship canal across the Isthmus of Darien, has the summit of its pass at 466 feet.§ The amount of subsidence to

---

* "Central America," page 131.
† "Naturalist in Nicaragua"; by Thomas Belt, F.G.S., page 35.
‡ Admiralty Chart, 2021.
§ "TheIsthmus of Darien"; Geograph. Mag., April 1878, page 81.

permit the waters of the two oceans to mingle is, therefore, comparatively little; not more than that of the high land above Liverpool, and that was submerged during the glacial period; the effects would, in a great measure, depend on the extra depth to which the land might sink. If this had been considerable the Gulf Stream would no longer flow into the North Atlantic, and a colder, or glacial climate must occur both in Europe and North America; and Britain would be placed under circumstances such as are recorded on the rocks as having occurred during the glacial period. But the transfer of the hottest of the equatorial water of the Atlantic into the Pacific would have other effects. A greater amount of vapour would there be supplied to the atmosphere, an increase of the snow-fall would, therefore, occur, augmenting the size of the glaciers in the Himalayas, on the Andes, and in New Zealand.

No absolute proof has as yet been obtained that the Isthmus has been thus sunk beneath the sea; it was hoped, that during the construction of the Panama Canal, some competent observer might have been able to decide the question, but there are valid reasons for considering that such had been the case. In the notice of Lieut. Wyse's survey of the Isthmus of Darien, during 1876-77, it is stated that a communication has evidently existed between the two oceans at a recent geological period, but the epoch cannot be fixed owing to the paucity of fossils.* Colonel T. S. Heneken considered "that a channel or sound may, during some part of the Tertiary Period, have existed by which some few tropical shells may have migrated from one ocean to the other;" he remarks, "that the Isthmus of Panama is not merely narrow, but low land, the Isthmus nowhere attaining

* Page 81.

1,000 feet."* Mr. Philip P. Carpenter regarded no less than 110 species of shells, found in both seas as being either identical, or so nearly allied, that they may prove to be identical, and twenty-six and upwards of analagous but distinct species. He asks "is it possible that some intercommunication may have been been correlative with the glacial conditions of the European seas?"† According to Mr. Verril and Mr. Alexander Agassiz, as quoted by Professor Wyville Thomson, "on either side of the Isthmus of Panama the sea urchins are abundant, they belong, on each side, almost universally to the same genera, and, in most cases, each genus is represented by species, so closely resembling each other in appearances as to be hardly distinguishable." Professor Thomson has arranged a list of a few (eighteen) of the most marked of these, from the Caribbean and Panama sides of the Isthmus, in parallel columns.‡ Mr. John Baily alludes to the number and magnitude of sharks in Lake Nicaragua,§ and it has been suggested by others that these and other fishes of a marine type, abounding in this lake, are descendants of those existing there when the lake was submerged, which might have coincided with the Glacial Period.

It is stated by Mr. Wallace that the Isthmus of Panama has certainly been submerged more than once in Tertiary times, and this subsidence, if considerable, would allow much of the accumulated warm water, which initiates the Gulf Stream, to pass into the Pacific, bringing about a cold period, resulting in

* "Tertiary Beds in San Domingo," Q. J. G. S., Vol. vi., page 43.

† Mollusca of the West Coast of North America." Brit. Assoc. Report; 1856, page 363.

‡ "Depths of the Sea;" page 13.

§ "Central America;" page 129.

glaciation in the northern hemisphere.* He considers that the last separation of the two Americas was of recent date, as shown by identical species of fishes on both sides of the isthmus.†

From what has now been stated, it would appear that writers of the history of the reign of the Great Ice King, have committed some great errors; many records, written indelibly on the rocks and on rock fragments, have been overlooked, or the details contained in the accumulated materials (Moraines and Boulder Clay) have not received sufficient consideration. Nor has a proper distinction been made between what has resulted from the action of glaciers on land, and what has been carried down from them and been deposited on the bed of the sea; but all have been classed together under such terms as glacial or northern drift and boulder clay. In contrast to this view it is here contended that the one consists of moraines formed on land by the direct action of glaciers; the other of clay, resulting from the grinding of rocks beneath the ice and carried down to the sea by sub-glacier rivers, into which clay erratics have dropped from bergs and floes as the ice melted.

Feeling compelled to call in question the opinions of Geologists who have considered the subject, I have done so in no captious spirit, but from finding their views incompatible with what I have found registered in the Geological record; at the same time, I have endeavoured to give a reason for the faith which is in me!

* "Island Life," page 146.

† Page 278.

THE BASE OF THE KEUPER IN THE NORTHERN PART OF WIRRAL.

By H. C. Beasley.

The division of Stratified Rocks into groups is so very necessary to their orderly arrangement in our minds, and for purposes of reference, that it was the first work of our early geologists; and so distinctive were the features of the various divisions that there seemed no great difficulty in broadly designating them. But when they came to be studied more in detail and in a greater number of sections, it was found to be not so easy as was first imagined to assign to them their actual limits. The boundary between the Trias and the Lias above has been bridged over by the Rhœtics, and the line to be drawn between them and the Lias is hardly yet settled. At the base of the Trias, what was considered the line between two great divisions of the series is now in a very uncertain state, and I expect before long that it will be very clearly shewn that in certain places the Permians pass gradually into the lower division of the Bunter.

At the meeting of the British Association in Liverpool in 1854, Mr. Hull described the beds from the base of the Red Marl, downwards as

1. Water-stones.
2. Upper soft red variegated Sandstones.
3. Coarse red Sandstone and Conglomerate.
4. Lower soft red variegated Sandstone.

He evidently included what we now know as the basement beds of the Keuper in the water-stones, for farther on he shows "that the conglomerate beds and the water-stones form two conglomeratic (and often calcareous) horizons, and that from the base of the water-

stones downwards the new red sandstone might be considered as a deposit of soft variegated sandstone, without pebbles separated into two nearly equal portions by sandstones of a harder quality, coarser grain, and generally conglomeratic, the whole presenting four eras in the history of the new red sandstone in England, during which similar conditions of sea and land maintained at alternate periods." Now, however much we may be inclined to differ from Mr. Hull in applying this scheme to the whole of the Trias of the Midland Counties, I think that his general idea as regards our own district has much to recommend it. And at first sight we should be inclined to regard the whole as one series, with only two conditions alternating with each other, without any break of continuity. On the other hand, the presence of numerous indications of a considerable fauna and flora in the Keuper, and their absence in the Bunter in this country, and the intercalation on the continent of a considerable thickness of calcareous deposits between the two series, would point to a more considerable break between the upper soft sandstones of the Bunter and the Keuper Conglomerate than between their representatives lower down in the series. Considerable importance must, therefore, attach to all sections in which the normal (or unfaulted) junction is exposed.

The Government Surveyors decided to consider the lowest bed of conglomerate as the actual base of the Keuper.* The reasons for assigning a definite well-marked band are obvious when we consider the practical object of the Survey, and for their purpose probably no better line of division could have been adopted; but at the same time, when considering the more theoretical aspect

* Third Edition Description of Country round Prescot, page 15. Also Geology of Neighbourhood of Chester, page 6.

of the subject, I trust I may be pardoned if I do not implicitly follow the lower boundary as laid down by them, for I think they would hardly contend that Keuper conditions absolutely set in at that particular point, or that we have not in some instances indications of a gradual rather than sudden change marked otherwise than by a bed of conglomerate.

The best exposures of the base of the Keuper are just now to be seen at Flaybrick Hill, where, in addition to the sections previously visible, some fresh ones have been opened within the last few months. At the N.W. corner of the quarries there is a section which has been exposed for many years, and which has been photographed—a copy being, I believe, in the portfolio of the Society. Owing to our grimy atmosphere the section is not very clear, but a bed of light coloured thin-bedded sandstone rests on the Bunter, and above it are ten or twelve feet of very pebbly sandstone. Along the western boundary an almost continuous section has lately been opened from near the section just mentioned, nearly half way to the southern boundary; and what is of more interest, a considerable surface of the base has been laid bare, and shews a bed of grey current-bedded shale mixed with a pinkish conglomerate. This follows the irregularities of the surface of the Bunter, which are clearly shown. There is no strongly marked division between this and the Bunter, but the line is clearly traceable when looked at closely, and the conglomerate and shale seem to work down into the Bunter for an inch or two, so that the division forms a very jagged line. The thickness of the shale and conglomerate is from two to six inches, and above it lies the pebbly sandstone, of which some ten or twelve feet remain in some places. I should remind you that it is

said that about 75 feet of building stone was removed from above the present surface many years ago. The whole of the rock, both Bunter and Keuper, in these sections is generally of a warm cream colour.

About the middle of the quarry, however, another section occurs offering a great contrast in colour, the Keuper being of a brilliant red, whilst the Bunter is variegated with red, orange, and yellow.

Keuper Conglomerate—a hard false-bedded rock, full of pebbles and small cavities, with in one place a patch of white micaceous sandstone, full of clay galls, and but few pebbles and no cavities, apparently lying upon it, but the junction is not clear .. .. 8 ft. to 10 ft.

This rests on the Bunter much in the same way as in the section last described. The Bunter in its upper part is of the same brilliant red as the Keuper, and weathers into cavities, but is quite free from pebbles or clay galls, and of a finer grain. Lower down it is quite compact, and assumes the bright yellow colour common to the rest of the Bunter in the quarry. The cavities, both in the Bunter and the Keuper, are filled with earthy matter, which quickly weathers out on an exposed surface, and in a hand specimen may be at once removed by a few taps of the hammer.

The line of division between the Conglomerate and the Bunter may be traced for some distance along an east and west section here. Following the dip of the beds to Tollemache Road, the base of the Keuper would be several feet below the road; but a fault occurs here which brings it up about ten feet above the road level on the east side of the road. You will, most of you, remember that a fault runs along the road here, and between it and another fault about 130 yards further east, the strata are forced up about 20 feet, although, from

the hade of the eastern fault, the movement might have been expected in the opposite direction. In the mass of rock here exposed there are several sections to be seen, both E. and W. and N. and S. Beginning at the north the face abuts on the road for some distance, and then is cut back a few yards; here the section is

		F.	I.
Keuper.	*a.* Irregularly bedded Sandstone with patches of conglomerate and clay lumps,	10	0
	b. Conglomerate of quartz pebbles, and fragments of sandstone mixed with Sand and marl,	0	3
	Bunter weathering into cavities near the top.	6	0

Following the bed *b* of conglomerate along the N. and S. face southwards, it seems to throw off a descending branch, which I shall call *b* 2; but this is not very distinct at one point, and there seems to be merely a dividing line between the Bunter and Keuper Sandstone in a vertical direction for several inches, and hand specimens may be obtained showing both beds. However, the thin bed of Conglomerate soon appears again, running obliquely downwards, whilst the original bed *b* continues unbroken nearly horizontally in its original direction, the two enclosing between them a bed of decidedly Keuper character, on the same level as the Bunter, a few feet distant. Unfortunately this becomes hidden beneath the spoil heap; but it is probably only a patch of Keuper occupying a hollow in the surface of the Bunter. Within a few yards of the first section the character of the upper beds has gradually changed, and the section at this point is

a. Irregular flaggy beds with clay-lumps ..	6ft.
More compact false bedded with pebbles	2ft.
Band of clay-lumps	1 to 26in.
False bedded with pebbles	2ft.
b. Thin bedded marl and sandstone	4in.
c. Rather coarse gritty sandstone	2ft. 6in.
b2. Conglomerate (quartz and clay and sand)	3in.
Bunter	—

Thin bedded patches of highly micaceous sandstone are here and there seen, reaching a thickness of 2ft., and thinning out again altogether in a distance of 3 or 4 yards. A little farther on there is an E. and W. section, which gives a good idea of the very irregular succession of beds in the lower part of the Keuper. Unfortunately the base is hidden, but must be not more than a foot or so beneath the bottom of the section.

The vertical height of the section is about 19ft. At the base is a bed of compact sandstone, with patches of pebbles, of which about 4ft. is exposed. Above this comes a layer of false bedded sandstone, about 1ft. 6in., pretty free from pebbles, but containing some fragments of marly shale, clearly separated along its upper surface from a bed of thin bedded sandstone about 1ft. in thickness. From this to the top, the section consists of a mass of false bedded sandstone full of clay-lumps, varying from one to three inches in diameter, with a few larger nodules near the base. This passes horizontally to the eastward into thin bedded gritty sandstone, with pebbles, and the transition, which is rather sudden, is curious. To the east of the second fault the base is not seen, but the floor of the quarry resembles the shale and conglomerate at the base of the Keuper in the western part of the quarry. A north and south fault, with a downthrow to the west, forms the eastern boundary of the quarry. The slabs which have been found in this part of the quarry, exhibiting casts of vegetable remains, probably come from the band of thin bedded sandstone mentioned in the last section described, but so far I have not found them in sitû.

I have detained you with a rather long, and, I fear, tedious description of the sections exposed in this quarry, but in no other place that I have seen is the base

exposed over so large an area, probably in consequence of useful stone having been found in the upper Bunter, which is unusual elsewhere.

Westward of Flaybrick, another N. and S. fault throws down the Keuper, so that the cutting of the new road through Bidston Hill runs through it all the way to the top, where the Bunter makes its appearance. The section close to the foot-bridge is

Thin bedded randstone free from pebbles	4ft.
Conglomerate and pebbly sandstone	10ft.
Bunter	6ft.

The lower part of the conglomerate seems to mix with the top of the Bunter in the same way as at Flaybrick.

In passing along the cutting before reaching the bridge, no one can fail to notice an irregular bed of large clay nodules, very brilliantly coloured in all shades of red, green, and grey. These are mostly found to have a concentric structure differing from others found elsewhere in about the same position, which retain their original lamination. The brilliant colouring has also spread partially into the surrounding sandstone. The colouring is, no doubt, due to iron salts; and I should suspect that the solution of these is connected with the molecular changes which have given rise to the concentric structure, they having originally been portions of a broken-up bed of laminated shale; but, of course, this is only conjecture on my part. They occupy a position about between the conglomerate and the thin bedded sandstone, say some 10 feet above the base.

Leaving these sections, and crossing Wallasey Pool, the base is seen at the lower entrance to the quarry at Poulton. About 2ft. of thin bedded marly sandstone rest on the uneven surface of the Bunter, and at one point a very small patch of clay and sand conglomerate

is seen at the base. On these lie the pebbly sandstone, becoming quite a conglomerate at the base.

LISCARD.—The members of this Society had some time ago an opportunity of seeing the cores from the well then being sunk at Sea View Road, and those who were there will remember that before reaching the Upper Bunter several feet of grey thin-bedded, rather fine grained, sandstones were passed through, and that between them and the Bunter a mass of conglomerate of clay balls and sand was interposed.

WALLASEY is, roughly speaking, equi-distant from each of the two last sections. The base is exposed in a narrow lane on the north side of the church, and again in the main road from Liscard to Wallasey Village, in both instances a little below the brow of the hill. In the lane a bed of marly shale, about six inches, lies on the uneven surface of the Bunter, and above it are about two feet of Keuper Sandstone, with few or no pebbles, but containing numerous cavities at the base. The section is not an extensive one, but a very fine section is shewn of the main road, some 20 yards in length and 15 feet in height; the rocks are identical with those in the lane. About 10 or 12 feet in all of the Keuper Sandstone is seen containing very few pebbles, and with no sign of conglomerate, except near the top. The upper surface of the Bunter is uneven. In the quarry, close to the site of the Old Windmill, the base is not seen, but the lowest bed is probably that seen in the road section, which it resembles, as the Bunter is seen a little way down the bank below. About four feet of this lower bed is visible, and above it a thick bed of conglomerate of remarkably coarse character, containing large fragments of a broken up bed of shale, very irregularly disposed. This does not extend any great distance, thinning out on

either hand whilst it is about four or five feet thick in the centre, and passes upwards into building stone. This bed has been described to the Society before, and many members have visited it, and I would only remark that it occupies the same position with regard to the base as the clay lumps at Flaybrick and Bidston, and those at Caldy, to be described later on.

There is a small patch of Keuper at Red Stones, off Hoylake, according to the latest Survey Map, but there is, I expect, some mistake, as the rock bears no resemblance to the nearest Keuper, and does very much resemble the pebble beds at Burton Point.

West Kirby.—There is a very good exposure of the Keuper and Bunter on the road from the station up Grange Hill. Unfortunately the Keuper is too high up in the section to be closely inspected, as before it dips down to the road level it is cut off by a fault, bringing it against the Upper Bunter. The Bunter consists of soft red and white sandstone; the line of junction is straight, following the dip, and shews no sign of erosion. The Keuper, of which about three feet in thickness is exposed, is rather full of cavities, and fairly free from pebbles. A thin bed of shale divides it from the Bunter.

A very good continuous section is also to be seen along Village Road, from the village to its junction with Monument Road, at the top of the hill. The lower portion is all through the soft Bunter. Nearly opposite Wetstone Lane a bed of sandstone occurs precisely similar in character to the Keuper just described; it is about two feet thick, and is overlain by soft Bunter Sandstone. This is what is marked in the Survey Map "Hard Band in the Bunter," and is mentioned in the memoir as occurring also at Thurstaston in the same position. The soft red Bunter extends the whole

distance up the hill to the corner of Village Road and Monument Road, where the Keuper Sandstone makes its appearance, resting on the even surface of the Bunter. The lowest bed is about 18 inches of thin-bedded coarse sandstone, full of cavities, but containing no pebbles; and above that six feet of more compact sandstone with few cavities and no pebbles.

Passing on to the quarries near the Water Works, I could find no section shewing the base, but from the presence of the Bunter a few yards off, and a little below the level of the bottom of the quarry, there is no doubt that the small quarry on the south side of the Water Works, reaches very nearly to the base. Here, above the more compact bed at the bottom, corresponding to that at the corner of Village Road and the road up Grange Hill, the rock becomes more false-bedded and encloses numerous clay lumps, similar to those at Wallasey and Flaybrick, except in colour.

Irby.—The quarries at Irby do not show the base of the Keuper, and the only place there, where probably the Surveyors saw it, is now quite hidden by vegetation.

There is a section at Mount Road (Boggans Lane), between Oxton and Storeton, which has been spoken of as shewing the junction of the Keuper and Bunter, but I think that this is not the case; the lowest bed does not resemble the Bunter, and contains a few pebbles. There is a bed of thin-bedded sandstone between this and the overlying conglomerate, just as in many sections of the base of the Keuper, but a very similar section occurs at Arno Hill, a little distance to the north, and there it is underlain by many feet of undoubted Keuper. In the same quarry, however, there is a very small section exposed which shews the base of the Keuper, resting on soft yellow Bunter.

At Storeton the base is not seen, though in a lane on the west side of the hill a bed of conglomerate is exposed, which is probably very near the base.

Having described the sections that I have been able to see in this corner of Cheshire, I should like to draw your attention to one or two points presented by them.

As has been the case in almost every junction of two sets of strata there are places where the transition is less abrupt than in others and where there are not those signs of erosion of the lower beds that one might expect to find. I cannot help thinking, however, that some erosion (though not necessarily sub-aërial) of the lower beds has taken place between the time of these deposits and that of the Keuper. Take the sections at Flaybrick and Bidston Hills, though the line of division is very irregular and uncertain, and the conglomerate *seems* to mix with the Bunter, yet the conglomerate preserves its character entirely to a certain point, and then gives place to the Bunter Sandstone, the sandstone does not gradually become conglomeratic. Now a considerable time may have elapsed between the formation of one bed and that of a superimposed bed, and yet not have been sufficient, or the circumstances favourable enough for the hardening of the lower bed, and this is what I should imagine to have been the case here. A strong current indicated by the coarse material deposited, passing over the compact but unindurated sand, to a certain extent worked up the pre-existing bed, and mingled it with the new deposit. In fact, where so much of the surface is exposed at Flaybrick, it is just as if the conglomerate with a pinkish tinge, had been worked up with a fine greenish tinted material, and well mixed with it. This is not so apparent in a vertical section, which might lead an observer to suppose that the lighter material was

part of the conglomerate itself, and that broken pieces of the lighter rock were mixed with it; but in the horizontal section it is seen that the lighter material is actually the matrix, and the conglomerate scattered through it. Another important point is the position of the lumps of marl, which, following the convenient term used by the Survey, I have called clay lumps. These in all the sections which I have seen do not lie at the base, but several feet above it, with a tolerably compact bed below them. They usually have the appearance of a bed of marly shale, having been broken up, and the fragments tossed into their present position without their having been much abraded, whilst other fragments of the same material, that have been more or less rounded, are generally associated with them. Wallasey, Flaybrick, and Caldy give good examples of this.

OBSERVATIONS ON MORAINES AND GLACIAL STREAMS IN THE VALLEY OF THE RHONE, AND NEAR GRINDELWALD,

By E. Dickson, F.G.S., with Note by W. G. Clay, M.A.

During the last session of the Society, two papers were read before it dealing with phenomena and facts directly or indirectly connected with Glaciers, one communicated by Mr. Holland and myself, the other communicated by Mr. Cumming.

The following paper is a brief account of a few observations made during a visit to Switzerland, in the early spring of last year, the chief objects of which were the following:—

(1) To extend the observations made with regard to the Arveiron to other glacial streams: (*a*) by collecting water and sediment from a number of streams in different parts of Switzerland, with a view of determining, if

possible, to what extent the sediment was affected by the variety of the rock through which and over which the glacier travels; (*b*) by collecting sediment from a stream, at different parts of its course, to ascertain what changes (if any) took place in the character of the sediment:

(2) To examine "ancient" and "recent" Moraines:

(3) To ascertain what traces (if any) there were of "ground moraine" or boulder clay, either under the ice itself, or where the glacier had retreated:

(4) And, lastly, to examine and consider the evidence for and against the erosive power of glaciers.

I will deal first with the examination of sediment deposited by glacial streams, and to avoid occupying too much space, will give the results of the examination of the sediment of a few of these streams, taken from two widely differing districts, viz.: (1) the Grindelwald valley (2) the Upper Rhone valley.

Two glaciers descend far into the Grindelwald valley, known respectively as the Upper and the Lower Glacier.

Both glaciers in their upper portion pass over gneissic rocks, and in their lower portion rocks of Jura Limestone. From the tongues of both glaciers proceed streams, which unite below the village to form the stream known as the "Black Lutschĭne." This flows down the valley for about three or four miles, and then combining with the "White Lutschĭne" flows past Interlaken into the lake of Brienz.

I carefully examined these streams, and collected sediment from points immediately below where the streams issued from beneath the glaciers and from points at varying intervals lower down the streams.

The first visit I paid to both glaciers was in March; the weather was very cold, deep snow lay on all sides,

To my surprise I found a tolerably powerful stream issuing from beneath the end of the glaciers, the temperature of the water being sensibly above the freezing point. The volume of the stream at a distance of 100 yards from the tongue of the Upper Glacier was thirty-four cubic feet per second. I subsequently managed to get underneath the ice forming the tongue of this glacier. I found the under surface of the ice covered with small angular fragments of a micaceous schistose rock, and similar fragments covered the surface of the bed over which the glacier was moving. This bed was of the Jura Limestone, but of these small fragments comparatively few were of limestone. I endeavoured to ascertain how far the mass of the ice was permeated with these small fragments, but was obliged to desist on account of the danger of interfering with the ice forming the roof of the cavern.

Similar fragments, composed for the greater part of schistose rock, occurred on the surface of the glacier.

The sediment collected from the bed of the stream consisted of a fine gritty sand, containing larger particles, chiefly of schistose rock, the particles both of the sand and of the rock being angular or sub-angular.

The sediment collected from the stream flowing from the base of the Lower Glacier was very similar in appearance, but on the whole finer. The stream was, in March 1890, when I examined it, 16 feet wide and 12 inches average depth. The volume of water would be about 62 cubic feet per second.

The particles, especially the larger particles, are angular or sub-angular. Of the larger boulders very few were of limestone, the majority being of gneiss or micaceous schists, although both glaciers travel over limestone for a considerable portion of their course.

After flowing seven miles the Black Lutschine is joined by the White Lutschine, which has its origin in the glaciers of the Monch and the Jungfrau.

I collected some of the sediment from the side of the stream at a point about three miles from the junction of the two streams. It differs from that collected from the stream in the upper part of the valley in its darker colour, and in the greater fineness of its component grains. I followed the stream several miles further down to Interlaken. The low land between the lakes of Thun and Brienz, now two miles apart, has been formed mainly by the sediment deposited by this stream. This deposit is not "a clay," and resembles the deposits in the valley of the Rhone now to be described.

The Rhone rises in the Great Rhone Glacier and flows down the valley called after its name. Below St. Maurice the valley becomes considerably contracted, and the river, after flowing through a deep narrow gorge, passes through the alluvial flat formed of the river deposits for a further distance of about 15 miles, until it enters the Lake of Geneva. A large number of streams, originating from glaciers many of them the largest in the Alps, and gathered on mountains composed of different kinds of rocks, flow into the Rhone. Many of these streams I examined, but found in all the usual characteristics of glacial streams. In none did I find the slightest trace of a "mud" or clay.

The deposit is similar in character all over this alluvial plain. When dry the deposit consists of a very fine micaceous sand, the little flakes of mica causing the sand to sparkle in the sunlight. When moist it does not form what would, strictly speaking, be termed a mud.

A detailed examination of this river deposit is given in the paper communicated to the Society by Mr. Holland and myself, and which appears in the present number of the proceedings.

In all these deposits formed by glacial streams, there is a general uniformity of colouring; viz : a lightish blue or grey, which, as Prestwich ("Geology" Part I.) observes, contrasts with the yellow deposits of open river waters.

Three conclusions may be drawn from the examination of these glacial stream deposits.

1 (*a*) That there is a great apparent resemblance in all these glacial stream deposits; sand or gravel, coarser or finer, according to the distance from the source of the stream.

(*b*) That the nature and character of these deposits depends more on the nature of the blocks and material brought on to the glacier, than on the character of the rock forming the bed of the glacier. (This latter conclusion is one I have some hesitation in submitting, but I think that on the whole the evidence warrants the conclusion).

(2) That as the streams flow a gradual mixing of the deposits takes place owing to the union of streams bringing down sediment, the spoil of various differing rocks—the sediment becoming gradually finer and finer.

(3) That none of these sedimentary deposits resemble what chemically or geologically speaking can be termed "a clay." I have never seen any deposit from any glacial stream that in any way resembles "a clay."

I now pass on to the second part of my subject.

During the glacial period one of the largest of the old Swiss glaciers was the one that came from the Canton of Valais.

This glacier filled up the whole of the Rhone Valley and its lateral vales, as far as Geneva, extended over the Lake of Geneva as far as the Jura, and reached several thousand feet above the valley bottom. The direction taken by the moraines carried on and in this enormous mass of ice has been traced by Professor Guyot. In these moraines are found, sandstones from the Dent de Morcles, granites from the mass of Mont Blanc, white granites from the mountains of the Upper Valais, serpentines from Monte Rosa, and granites forming the large blocks, which I will refer to presently, from the Val de Ferret.

There are still many traces left in the Valley of the Rhone of this enormous glacier, and I think that probably in no other part of Switzerland could the effects of undoubted land ice on a vast scale be better studied than in this Rhone Valley.

These moraines may be divided into two classes, viz., those moraines which consist chiefly of rocks from the highest mountain masses, and those chiefly of rocks from lower elevations, and from this fact it has been inferred by Professor Guyot that there were two periods in the history of the glacier; the earlier period, the one in which the glacier was larger, the latter in which it was smaller.

The Lake of Geneva is about 1,230 feet above the sea level, and in its deepest part exceeds 1,000 feet.

In places above Montreux, 2,000 feet above the level of the lake, where the turf was removed, the rock beneath was smoothed and striated. The direction of the striæ was N.N.E. S.S.W.

Boulders of granite (for the most part white granite) probably from the mountains of the Upper Valais, many

of them smoothed, several of them scratched, were embedded in a coarse sandy, gravelly matrix.

Of the old Moraines, abundant traces exist in the Valley of the Rhone.

Near Monthey, at the entrance of the Val d'Iliez (one of the lateral vales opening into the Rhone Valley), about eleven miles from the head of the Lake of Geneva, at an elevation of 400 feet above the valley, blocks of grey granite from the Val de Ferret occur in sufficient abundance to form what has been described as a rampart 3,000 feet long, 500 — 800 feet wide. One of the largest of the blocks is 63 feet long, 32 feet wide, and 30 feet high; contents, about 60,000 cubic feet (Charpentier). Unfortunately these blocks form a convenient quarry for road material, and are gradually disappearing.

Traces of former ice action occur in plenty all through the Upper Rhone Valley.

I found many traces of smoothed and striated rocks, boulders of all sizes and kinds in the higher portions (*i.e.*, 1,500 feet above the Lake), sand and gravel, fine and coarse, mixed with the stones, but nowhere till or clay.

I must now pass on to describe the recent Moraines, meaning by "recent moraines" those left by glaciers within historic times.

The Swiss Glaciers are liable to considerable fluctuations in their movements, having irregular periods of increase and decrease. For example, many passes now practically inaccessible, were traversed on foot, sometimes on horseback, and by troops between the 12th and 15th centuries.

The old Church records at Grindelwald shew that late in the 16th century Lutheran parents took their children from villages on the Haut Valais across the great Aletsch Glacier to Grindelwald for baptism (a feat utterly impracticable now), and I was informed that the bell of the new English Church at Grindelwald formerly did service for a church high up in the mountains, the site of which is now covered by the great sea of ice.

As Forbes has well pointed out, "These facts are "important as shewing that a very notable enlargement "of the Glacier boundaries was consistent with the "limits of atmospheric temperature, which we know "that the European climate has not materially over-"passed within historic times." Many glaciers, such as the Aletsch, Zmutt, and the Rhone are increasing; others, such as those which descend in the Chamounix Valley, are retreating. The latter seems also to be the case with the Grindelwald Glacier.

I was anxious, by careful personal observation, to ascertain—

1. The general appearance of a valley, from which a glacier had recently retreated:

2. The appearance, composition, and structure of a recent moraine, if the stones were rounded or angular, whether loose or cemented, the nature of such cement, and if smoothed and striated stones were as rare as represented by Mr. Cumming in his paper:

3. Whether these recent moraines resembled or differed from the so called moraines of this country:

4. The appearance of the rock under the glacier itself, and whether any traces could be detected of ground moraine or boulder "clay:"

5. Evidences of the erosive power of the Glacier.

Speaking generally, I may say that when I came to compare Mr. Cumming's conclusions, as contained in the paper referred to, with my own notes, I was surprised to find in how many ways our observations agreed.

The valley into which the Upper Glacier descends forms a ravine between the Wetterhorn and the Mittenberg. The surface of the valley was covered thickly with boulders. The north end of the valley was more or less blocked up with parallel heaps of sand, gravel, and stones, running across the valley. The heaps were roughly rounded, but the mass of material, sand, gravel, and stones, was heaped together without any sign of stratification. The sand and gravel were loose, the stones angular and of all sizes, some of the largest 10, 15, 20 tons in weight, were lying near the top of the mound. I looked carefully, but could not find one scratched stone. These mounds are undoubtedly terminal moraines, and indicate stages in the glacier's retreat. How long the glacier has taken to effect its retreat I have not been able to ascertain.

Through the centre of the moraine the stream flows, keeping closely to the mountain side on the west.

The stream flowing from beneath the tongue of the glacier was, when I examined it in March, 1890, about 17 feet wide; the valley for about 50 yards on either side of the stream ascended gradually, and it was very noticeable how all the stones below a certain line were rounded. Above this imaginary line angular stones of all sorts and sizes formed heaps stretching down the valley in an irregular line. The stones were not in any way cemented, as in the moraine described by Mr. Cumming. In the interstices there was loose, coarse,

angular, gravelly sand; but not to the same extent as in the moraines at the north end of the valley.

These irregular ridges extended for about 300 yards from the stream, succeeding which came a series of small terraces of gravel and boulders: the boulders being of all sizes, all sharply angular, and of many different kinds. On one of these terraces I found two pieces of limestone smoothed and striated, one weighing about 4 oz., and the other weighing about 2½lbs. There was also one large boulder weighing at least 8 or 10 tons, with the side smoothed and striated; with these exceptions I could not find in this or other recent moraines that I examined specially for this purpose, any other examples of smoothed and striated stones. Beyond this series of small terraces further to the eastward a steep slope stretched to the top of the valley. This slope struck me at once as being entirely different to the moraine heaps in the lower part of the valley, and to the terminal moraines at the north end. I found that the side sloped at an angle of 40°, and that the angular blocks were cemented hard and fast in a matrix of a fine sandy material. This cementing material was so hard that I had to use a chisel to obtain a portion of it. Climbing up the moraine was both difficult and disagreeable, the sand and stones cut one's hands and ruined one's boots. I felt no doubt but that this slope formed a side of a lateral moraine, and that the fine cementing material was the result of the attrition or the "kneading" process carried on in the body of the Glacier, which is referred to by Mr. Cumming in his paper.

Beneath the tongue of the glacier itself I found the under surface of the ice covered with small angular fragments, the bed was fairly smooth but not polished or striated. I here found a limestone block distinctly

striated, weighing about 6-7 lbs. lying on the bed, but not smoothed or striated to the same extent as the specimen found on the "Terrace." Some of the other stones were angular, but the majority were rounded as by water. I did not observe any stones in the ice itself, and I could not ascertain how far the sand and gravel interpenetrated the mass. There was nothing beneath the ice itself but these angular fragments and (comparatively few) stones; nothing whatever in the nature of a "ground moraine" or a boulder clay. I could see no evidence of any power possessed by the glacier of "churning" the deposit beneath. Although the surface of the bed was fairly smooth, still it was by no means absolutely so; there were irregularities, and the ice seemed where possible to adapt itself to circumstances.

I made similar investigations with regard to the moraines below the lower Grindelwald Glacier, but the want of space does not allow me minutely to describe them. The general characteristics of this valley are similar to those I have already described. The stream from the glacier has cut its way through a narrow gorge, twenty feet wide. I am inclined to the opinion that this is the work of the stream itself. The excavating power of a glacial torrent bursting forth and carrying with it boulders and gravel cannot but be very considerable, and I think that much of the excavation put down to ice is in reality the work of these streams. A beautiful example of a rounded, smoothed, striated surface occurs in this valley about four hundred yards below the end of the glacier. I merely mention this as a reminder that in these valleys smooth and striated rock surfaces are not nearly as common as is generally imagined. The *sides* of the valleys overhanging the glaciers frequently are so, but I submit that this rounding is frequently due

not so much to the glacier as to the avalanches and showers of stones falling from the mountains. Here again, as in the Upper Glacier valley, the lower part of the valley is covered with loose boulders, rounded if within the limit of the "flow" of the stream, angular if beyond this limit.

The same irregular lines of heaps of morainic debris, debris rising in terraces, the steep slope rising above the terraces, occur as in the Upper Valley. I measured one of these morainic heaps, and found it to be 66 feet high, the material lying at an angle of 30°. The blocks were all loose and angular, interspersed, especially towards the top, with loose, gravelly material.

Although I made careful search, I did not find among these morainic heaps a single smoothed or striated stone, and no trace of any ground moraine or boulder clay.

As regards the excavating power of glaciers, the subject is one of too complicated a character to deal with at the end of a lengthy paper. From my own observations of the glaciers and glacier valleys, I am inclined to the view that their power to excavate has been exaggerated. I saw no signs of it in either of the Grindelwald valleys, though the slope of the Upper Glacier bed is 27°, of the Lower 14°, as against 4° the slope of the Aletsch Glacier. In the case of both valleys the conditions were favourable for erosion; the slope was excessive, the main body of the ice was very considerable and the channel narrowed suddenly.

The glacier always acted as if it were formed of a viscous substance, adapted itself to circumstances—would go round rather than surmount an obstacle. An excellent instance of this "viscosity" is given by Professor Spencer, in the Geological Magazine for 1887, taken from a glacier in Norway.

In considering this question, I think the following points deserve to be borne in mind.

1. The effect of this "viscosity" using the word in the sense of "acting as a viscous body."

2. The very slow motion of the lower part of the glacier.

3. The fact that the erosion, to be considerable, must be by stones harder than the bed.

4. The fact that, as is shewn by an examination of the glacier stream deposits, a great portion of the sediment belongs to rocks which must have fallen from above through crevices, and which differs from the bed over which the glacier has travelled, and that, apart from the suspended matter, the sediment near the glacier is always coarse, more so than further down the stream.

5. The absence of evidence. There is no instance of a block having been seen torn off, and only a part of the bed is smooth.

6. The difficulty of reconciling eroding power with till producing action.

7. The fact that if a hollow began to be formed it would soon be filled with sand and debris, and the ice flow over it.

8. The effect of pressure.

As this latter point is one to which I think not sufficient attention has been directed, at my request my friend Mr. W. G. Clay, M.A., Trin. Coll., Cambridge, has kindly written me the following note, dealing with it, and generally with the whole question of the eroding power of glaciers.

NOTE BY W. G. CLAY, M.A.

The behaviour of glacier ice depends mainly on two things, its temperature and its pressure. And first as to its temperature—

The material of a glacier reaches it as snow which falls upon it from the heights above at various temperatures, for the most part in the form of avalanches, and brings with it huge quantities of detritus from the higher parts of the mountains. Neglecting the heat developed by the fall of the avalanches which is in great measure dissipated, the glacier ice enjoys three principal sources of heat.

1. After reaching the glacier, the snow undergoes a process of compression which transforms it into ice. The work done during the compression makes its appearance in the higher temperature of the resulting ice.

2. The glacier is constantly descending, the work done by gravity is expended in overcoming the so-called "viscosity" of the ice and also appears in the form of heat. The amount due to this source can be computed with ease. It is sufficient to raise the ice 1° C for every 700 ft. of fall.

3. Heat is constantly streaming into the glacier from below.

To estimate the importance of this, it must be borne in mind that the conditions of things below a glacier is utterly unlike that prevailing on ordinary open ground where the fluctuations of temperature are due chiefly to radiation and its converse absorption, the even and less striking effects of conduction being usually overlooked altogether. But it is when the ground is covered with a coating of snow effectually cutting off all radiation, that the importance of the unceasing flow of heat from below is manifest, though, owing to the large latent heat of ice it is able to do little in the way of melting the snow, yet it can raise at any rate the lower layers to the melting point, and thus maintain a temperature high enough to prevent harm to vegetation.

The exact effect of this flow of heat is difficult to estimate accurately, owing to the scanty data available as to temperature underground. It may perhaps be taken that the average increase of depth for a rise in temperature of 1° F is more than 50 ft. and less than 100 ft. Since the mean conductivities of rock and of ice are in the ratio of 5 to 2 it follows that if the rise of temperature in the rock be 1° for every 100 ft. the ice may be at a temperature of 22° F. 400 ft. above the bed, consistently with its lower surface being not less than 32°, while if the rise is 1° in 50 ft., the ice may be at 22° 200 ft. above the rock. This is of course based on the assumption, probably accurate enough, that the flow of heat is steady.

On the whole, in view of the many causes tending to raise the temperature of the glacier ice, and the absence of causes tending to lower it, it seems fair to conclude that the temperature of a glacier, in European climates at any rate, is but little lower than 32°, while at the bottom the ice will be at the melting point.

Next, as to the pressure of the ice. Were the glacier at rest, this would be simply, that due to the superincumbent mass of ice, amounting in the case of a glacier 1,000 feet thick to about 390 lbs. per square inch. But if the glacier is to do any eroding work, the parts in contact with the rocks must be in motion, and during the motion the pressure exerting locally may vary indefinitely from the statical pressure spoken of above. A simple illustration will make this clear.

Suppose a pound weight hanging at the end of a piece of string. The magnitude of the tension of the string is simply the weight of one pound, but if the weight be lifted up and let fall, the tension in the string at the instant it becomes taut is very much greater.

How much greater it is depends on the elasticity of the string and the height of the fall; but were the string wholly inelastic, then, however slightly the weight was raised, and however slowly it was falling when checked, the impulsive tension of the string would be infinite in amount. The same is true in motion of every description, and in the case with which we are concerned, that of ice moving over an uneven surface, the pressures exerted on particular projections from the bed may vary within very wide limits.

So far we have considered separately the temperature and pressure of the ice near the glacier bed, but the importance of the results arrived at in discussing the eroding effect of the glacier lies in the fact connecting them, namely, that increase of pressure lowers the freezing temperature of water, or in other words, that ice cannot exist at a given temperature under more than a certain pressure.

Now we have shewn above that the internal heat, though not sufficient to melt more than a small portion of the glacier ice near the bed, is able to raise it to the maximum temperature at which it can exist as ice; and this temperature will be the melting temperature at the mean pressure on the bed, which is very much the same as the statical pressure due to the ice above. It thus appears that the ice is in a highly unstable condition—a condition in which any small increase of pressure may convert it into water.

Now consider the ice in the neighbourhood of any obstacle, say a projection from the bed of rock on which the glacier rests. It retards the ice behind it, and increases the pressure in its neighbourhood. The inevitable effect must be, that immediately surrounding the obstacle, at any rate on its hinder side, we have not

ice but a cushion of water. This water will be continually flowing round the obstacle to freeze again below and fill up the vacuum caused by the advance of the ice, and will be as continually renewed by the ice pressing on from above. Of course the flow of water will to some extent wear down the obstacle, but its effect is obviously infinitely less than that of a solid substance planing down the surface of the rocks. It seems then impossible to escape the conclusion that glacier ice is by itself about as imperfect a denuding agent as can possibly be imagined.

But the limitations of this conclusion must be carefully recognized. It is not intended to deny, nor is this theory in any way inconsistent with the fact that rocks imbedded in ice can exercise most powerful scoring and abrading effects. Just as a diamond-cutter embeds a diamond in "fusible alloy," a substance utterly incapable of resisting the pressures exerted during the cutting process, so the deliquescent ice and water may be easily able to sustain the different pressures exerted over the surface of a boulder, one corner of which is engaged in scratching a wall of rock.

Gravel and sand lying on the bed of a glacier will no doubt considerably help the denuding process. By direct friction between the glacier and its bed, probably little is effected. In the first place it is doubtful whether the ice is usually in direct contact with the rock. It seems far more likely that there is a small cushion of water due to the melting of the ice by the underground heat, and this will of course reduce the frictional resistance to practically nothing. In the second place where it is actually in contact, it seems open to doubt whether there is any slip at all, and whether the frictional resistance is not sufficient to keep the contact layer of ice at rest, in which case, of course, no erosion would take place.

Three other points remain to be considered—

(1.) In order that denudation may proceed effectively the denuding and denuded surfaces must be kept in proper condition, in other words the detritus must be removed. How is this to be effected? The stream, running beneath the glacier, will no doubt carry with it a good deal of spoil, but this stream can only flow freely where the glacier does not bear directly on the rocks, which can only be the case over a very small fraction of the surface covered.

In other parts of the bed we can only conceive of the detritus as being gradually rolled down by the ice, and moving even more slowly than the glacier itself; and where there is a cushion of water below the ice it will move but very little, if at all, faster than the ice itself; and as the carrying power of water depends on the velocity with which it is moving, it has probably little effect in scouring the rocks.

(2.) However the denudation takes place, it requires a consumption of energy to effect it. Whence does this energy come? We have energy of position in the ice as it reaches the glacier, and we have heat energy in the rocks below and in the ice above. The second law of thermo-dynamics forbids us to expect any assistance from the last, while the rocks appear to devote their energy to spoiling the ice for denudation purposes.

There remains only the energy of position, but it is a very small portion of this that is so employed. It is only the energy of the ice immediately above the rocks that is available. The energy of position of the rest of the ice is expended, as was pointed out above, simply in heating the ice.

(3.) It is customary to compare a glacier to a river, but the river it resembles is not the mountain torrent

tumbling down the rocks and rolling over and over the pebbles in its bed, but rather the stately stream, meandering through an almost level plain. Now in the lower part of its course a river rarely denudes its bed, it frequently deposits alluvium in it, but in the majority of cases it does neither the one nor the other. Do glaciers resemble rivers in this respect also? A glacier can and does carry with it an enormous mass of alien material, but a certain proportion of this can hardly help finding its way down to the bed. A limited amount of loose material will usefully assist denudation, but a thick bed of it will effectually shield the rocks below.

It only remains to consider how far the erosive effects of glaciers depend on their thickness.

Certainly if the glacier is sufficiently thick, and sufficiently cold in the centre, it may be able to keep the temperature of its lower surface so cold that the pressures exerted in removing obstacles are not sufficient to melt it. But otherwise it seems that mere increase of thickness makes very little difference. For it is not pressure by itself, but differences of pressure that are important. A mountain stream dashing against a boulder flies off at a tangent, and may leave a vacant space below, the difference of pressure above and below is great here, but when the same boulder lies at the bottom of a deep river, the water closes round it below and the difference of pressures is small. With a glacier it is just the same, and if the ice at the bottom is in a deliquiescent state, it seems that the effect of an increased pressure would be to make it not more but less active in its movements.

THE TRIAS OF THE VALE OF CLWYD.

By T. Mellard Reade, C.E., F.G.S., F.R.I.B.A.

The Vale of Clwyd has always had an attraction for me, even in the Geological Map. The tongue of Triassic Sandstone forming the bottom of the vale, and stretching far into the land between the mountains of Denbighshire and Flintshire, is a singular and unique phenomenon.

When, however, we view its fair and rolling plain from the hills on either side, and especially from the high ground above Denbigh, the richness of the landscape, due as it is to this geological feature, adds greatly to our interest. With a view of more clearly understanding the structure of the vale, and in continuation of my investigations on the origin of the Triassic Sandstones, I spent a fortnight last summer in examining all the sections I could find in the neighbourhood of Denbigh, Ruthin, and St. Asaph. Judged only from the map, this tongue of Trias looks like an inlet of the Triassic Sea (or Lake as some think), and will hardly fit in with any general riverine theory of the origin of the Trias. In the earlier maps of the Geological Survey, the Triassic Sandstone is shown as simply filling up a trough in the Palæozoic rocks. In the last published maps, the geology of the vale is shown to be not quite so simple as this, so that the preservation *intact* of a Triassic inlet, which *prima facie* seems so singular an occurrence, considering the untold millions of years that separate us from the Triassic period, fortunately for the physical geologist has not to be accounted for.

The labours of Mr. Strahan and Mr. Tiddeman have disclosed the fact that a considerable fault, called by them the Vale of Clwyd fault, runs down the eastern side

of the vale, and drops the Silurian and Carboniferous, and to some extent, it is believed, the Trias, to the westward. The throw of this fault is estimated by Mr. Strahan at 2,000 feet; and he shows very clearly that the Carboniferous strata had been folded, faulted, and very considerably denuded before the Trias was laid down.

The Vale of Clwyd is primarily due to post-Carboniferous faulting, and secondly, to pre-Triassic marine denudation, so that the surmise, that it formed an inlet in which the sands of the Triassic sea were deposited, is borne out by further examination.

With these preliminary observations, I will now proceed to describe the various sections and observations on the Trias I was enabled to make during my sojourn near Denbigh.

Llanrhaidair.

At the pretty little village of Llanrhaidair, on the west side of the vale, and about three miles south-east on the road to Ruthin, the general character of the Triassic Sandstone of the Vale of Clwyd may be seen. It is a bright red sandstone, without pebbles, and much current-bedded. A section may be seen at the side and back of a cottage, on the east side of the main road, and in a gulley which runs up by the church westwards. Several exposures can be seen in this deep, picturesque dingle, and also in the road running parallel to it. At the top of the dingle, the Carboniferous Limestone is seen, and also in a quarry higher up. I searched closely for the actual junction of the Triassic Sandstone with the limestone, but the ground is so covered with soil and timber, as well as bearing marks of artificial excavation and filling up, that I could not find it. I reduced its position, however, to a limit of about 20 feet, and have no doubt that the junction is a fault, with a downthrow to the east.

In the limestone quarry are siliceous concretions uncommonly like flints, which may possibly be the origin of some of the puzzling "flints" in the Drift of Cheshire and Shropshire.

Pont Cerrig.

A little over a mile further on the Ruthin road, still in a south-easterly direction, a stream, having its rise in Rhyd Ganol, shows a section of the Trias. Walking up the stream from Pont Cerrig in a south-westerly direction, a section of soft red sandstone, current-bedded, with a dip to the north, is the first section seen; and a little further on, another section of similar sandstone, having a thin seam of yellow colour, containing small quartz pebbles in a clayey matrix, and dipping 8° N. occurs. These are undoubtedly Triassic. A small exposure on the side of the stream about 38 yards higher up shows a purple sandstone which also apparently dips 8 degrees N.; beyond this is a purple micaceous sandstone which seems to have a northerly dip. A purple marly rock dipping about 13 degrees N.E. next shows, and this follows up the stream until the undoubted Silurian rock comes in with a high dip west by north.

The purple sandstones are probably Carboniferous, but the Triassic Sandstone apparently is conformable to them. Such, however, is the rank luxuriance of vegetation in this dell that it was impossible with the time and means at my disposal to definitely prove this.*

Railway Cutting.

Where the Ruthin road crosses the railway about 1¾ miles south-east of Denbigh station the railway cutting

* Prof. McKenny Hughes (Proceedings of the Chester Nat. Hist. Soc. No. 3, p. 22) says "In the bed of the stream which runs down by Pont Cerrig and Pentre from Rhyd Ganol, the junction of the New Red and Silurian is seen in places to be a fault." This does not correspond with my observations.

reveals a good section of the Trias. The rock is soft red sandstone having a dip of 22°, west 10° north, in one place where I took observations, and in another close to a dip of 28°, west 12° north; it is evident that this is current bedding. The rock is covered by fawn coloured Boulder Clay.

Quarry near Cil Owen.

About 100 yards above the foot bridge to Cil Owen, on the left bank of the River Clwyd, a short distance from St. Asaph at the edge of the cover, is a natural rock exposure, and about 60 feet further on is a sandstone cliff which has evidently been quarried. This rock is also soft red sandstone, but displays strong current bedding, not following parallel directions as in the preceding examples, but one set of planes crossing and truncating another set of planes in a confused manner.*

Further south-east, in the cover, is a deep wall-sided ravine, or canŏn, in soft red sandstone, now nearly dry, and still further north, in the cover at Llanerch, opposite Wern dû, is a small cutting, or disused quarry, in a ravine called Nant Cythrael in similar rock.

River Elwy.

On the right bank of the Elwy, just above Pont-yr-allt-gôch, there is an exposure of a thin bedded purple sandstone, very soft when weathered, but very hard when not so affected, and in the wood at the sharp bend of the river, about one-third of a mile above the bridge, still on the right bank, the purple sandstone out-crops about half way up a very steep slope difficult of approach. This sandstone is much weathered, and is of a dull hue, looking more like sun-dried earth at first view. On fracture it proves to be a rotten thin bedded

* This appears to be the quarry illustrated by Prof. McKenny Hughes. Proc. of Chester Soc. Nat. Science, No. 3, p. 23.

micaceous sandstone, originally purple in colour, and dipping 8° north-east. In the bed of the river, between this point and the bridge, there is an exposure of the same rock, here rounded by attrition, harder and less weathered. The bedding is flaky, with a dip west-north-west, but this may be current bedding. This sandstone is marked as Trias on the map, published in 1850, but it has been ascertained since that it belongs to the Carboniferous, and is part of a series overlying the limestone, but at the time of the first survey unrecognised as such.

East Side of the Vale—Cross Keys.

In a lane, just above Cross Keys, about two miles south-east of Bodfari, there is a small exposure of soft Triassic sandstone, worn down by cart wheels. The dip of the current bedding is south-west. There is a good deal of red sand lying on the rock between it and the drift, and that this is general may be seen by the prevailing red colour of the roads.

At Llandyrnog the dressings of the old church have been restored with Keuper Sandstone from Runcorn, which looks a pale greyish red in contrast with the original red stone of the neighbourhood, which has been left in where sound. This church, it may be mentioned, possesses a good oak roof.

Quarries near Llanbedr Farm.

The best exposure of the Triassic sandstone is seen in the quarries on the north-side of a brook, near Llanbedr Farm. The rock at the east-end of the eastern-most quarry is bedded in remarkably true and parallel planes, and is laminated with a tendency to split into flakes, the grain is fine and the colour deep red, which seems to get brighter with weathering.

The quarry is not being worked now, but there are many squared stones lying about, and others trenched out with the pick ready for getting. The dip of the bedding planes is 30°, west 12° north. Towards the west-end the bedding becomes irregular, and curved with curved laminations, having the same general dip west-wards, so that it would appear that the inclination of the dip planes, though so true, is the result of deposition, not after-movement. There are three separate quarries close together where stone has been got at one time or another, and it is said that Ruthin Castle was originally built of this stone, though the stone of the modern part came from Chester, I am informed.

The rock is seen also in the cutting of the main road at Hirwyn, and where the road crosses the dell, worn out by the brook running down from the quarries. Here the dip is about N.W., with current bedding across it, weathering out in a peculiar manner.

Ruthin and Ruthin Castle.

On the road into Ruthin, from Llanbedr, just before entering the town, under a private foot-bridge over the road, is another cutting in the soft red sandstone. It is fissile, and dips 22° N.W.

The red sandstone may be seen under the foundations of parts of the old portion of Ruthin Castle. Where I examined it the rock was very red, soft, and fissile, and had a dip of 19°, north 10° east, and at another place 18°, north-west, showing pretty clearly that it is false-bedding. Some of the old walls of the castle were faced with red sandstone, which might have been quarried on the spot, as the castle evidently stands upon a spur of the Trias.

General Characteristics of the Trias of the Vale of Clwyd.

The character of the Triassic Sandstone, in the Vale of Clwyd, it will be seen from the foreging description, is remarkable uniform. Generally speaking it is a fine grained impure quartzose sandstone of a bright red colour, crumbling readily in the hand. It does not sparkle in the sun like good building stone, and when viewed under a microscope it is seen that there is very little deposit of secondary silica on the grains, which when free from the incrustation of red dirt distributed through the rock and adhering like dust to the grains, have a resinous lustre. Compared with the shore sand at Blundellsands the grains of the rock at the quarry, near Llanbedr farm, are, on the average, smaller, but are more irregular in size, possessing about the same degree of roundness. At Cil Owen and the railway cutting under the Ruthin road, south of Denbigh, the grains are rather larger and more rounded. When I say the sandstone is impure I mean that the quartz grains are much mixed up with foreign matters, in the shape of dirty iron oxide, which have prevented the stone from being converted into good building stone by the cementation and deposit of crystalline silica.

The whole of this sandstone is generally considered to be Lower Bunter. As it rests, so far as we know, directly on the Carboniferous rocks, and it possesses the features of the Bunter Sandstone, it probably is the lower part of the Bunter. I have, however, but little faith in the validity of the divisions of the Bunter, speaking in a geological sense, and I question very much whether there have ever been any pebble-beds deposited in the Vale of Clwyd.

Geologically the rock may represent nearly the whole of the Bunter. There is no representative of the Keuper present, or at all events known. If the Keuper Sandstones and Marls have ever been present, they have been destroyed by denudation.

This is a question on which we can only surmise with but slender basis of fact on which to work.

The apparent dip of the rock, though often high, appears to me to be more the result of original deposition, than after movements.

Drift.

It will be seen, from these descriptions, that there are not many exposures where the Trias can be studied, this being due to the cover of Drift which overspreads the Vale. Had some of the beds of rock been of a hard nature no doubt we should have seen more of the Trias. As it is, it has been worn down uniformly, so that the exposures principally occur on the borders of the Vale where the tributary streams cut into the rock. There is no doubt that the Vale was considerably scooped out before the Drift was deposited, as the Triassic Rock rises on each side considerably above the centre of the Vale.

On the Elwy, below St. Asaph, is to be seen a good section of the Vale of Clwyd Drift. It consists here of a bed of Boulder Clay of a light brown color when resting upon a bluer clay, which probably becomes true Till below the level of the river, but as there is no exposure to the rock-bed this cannot be alleged for certain. Upon the Boulder Clay rests a series of irregular current-bedded and laminated sands and gravels capped with Boulder Clay. This Boulder Clay and Sands possesses all the features of the Low-level marine Boulder Clay of Lancashire and Cheshire, modified of course by the

local conditions, and containing a larger percentage of local rocks.

The usual marine shells in a fragmentary condition are to be found in this drift.

At the embouchure of the valleys of the various tributary streams that drain into the Clwyd the Drift changes its character, and becomes more stony and full of local rocks. Good examples of this are to be seen in the Ystrad, near the Denbigh Waterworks, below the road from Denbigh to Ruthin, and in the scarped face of Drift which crosses the same road about 1½ miles from Ruthin, not far from the "Drovers' Arms." This is evidently a river terrace cut in the Drift. That a good deal of Drift has been removed from the Vale of Clwyd there is plenty of evidence from the scarped terraces that are to be observed cut in the Drift all along the Vale. The Vale of Clwyd has evidently been an estuary during the laying down of the marine Drift, and affords further evidence of the fact that I have dwelt upon in previous papers, that the Low-level Boulder Clay and Sands were mainly deposited in comparatively shallow water, and that the bulk of the materials are due to the denundation of the land on the lines of the existing watersheds and river basins.* The prevalence of sandy Drift is doubtless due to the soft Triassic Rocks beneath. The underlying blue Till may be justly considered to be the product of land ice.

Does the Vale of Clwyd Trias throw any light upon the general question of the origin of the Trias?

My investigations being undertaken mostly with the object of unravelling this knotty question, I will now proceed to discuss the bearings of the preceding observations.

* See Q. J. G. S. (1874), p. 127.

The most striking feature in the geology of the Vale is the fact that the Triassic sandstones, which occupy its floor, show an almost absolute independence of the surrounding rocks.

If the sandstone had been laid down by a river draining a distant area, as surmised by Professor Bonney, or even consisted of sand blown up from the sandy delta of such a river, the surrounding high ground would certainly have contributed to, and mixed local materials with it.

The Drift, as already described, gives a good illustration of how local materials would constitute a large bulk of the deposits in such a valley if we discount the difference of conditions of the two climates. There is no doubt there has been a subsidence of the Trias along the lines of preceding faults, and considerable denudation of the Triassic Sandstones, so that if they were replaced in their normal positions the bottom of the Vale would be considerably raised.

But *pari passu* with this the surrounding hills have been denuded. What can have prevented the mixing of the local rocks with the red sandy deposits? It appears to me that there must have been a considerable depth of water over the Vale, so that the shore lines of a lake or inland sea, or sea connected with the ocean, as I have suggested,* whichever it may have been, should have been distant from the area of deposit, and a considerable amount of the land have been submerged. It is a reasonable inference that if sub-aerial conditions prevailed near to the area in which the sandy deposits accumulated, the streams would inevitably have brought in their quota of local materials of a coarse sort, which

* Physiography of the Lower Trias, Geol. Mag., Dec., 1889.

we should find buried with the sand, but this occurs to a very small extent, and only near the base. That under deep-water conditions, the sandstones could not have been laid down in a lake or inland sea further drives us to the only remaining explanation—namely, that they were accumulated in a *tidal* sea of considerable depth. The absence of the quartzite pebbles so frequently found associated with the Bunter Sandstones, may be, and probably was, due to the prevailing local conditions, rather than to the rocks being at any definite horizon in the Bunter. Tides would have but little force in a fjord, as compared with a through-channel. In Lancashire and Cheshire, where the pebble beds are developed, the Trias forms a neck communicating with a large inland area of Triassic Rocks, and this again is conterminous with the Trias of Mid-England, which is connected along the Severn Valley with the Trias of Devonshire. It is just at the constricted parts of the Triassic area, such as along the estuaries of the Mersey and Dee, or on the stream lines along this "strait," as at Holt in Cheshire on the borders of Flint, at Market Drayton, and at Bridgenorth in Shropshire, or elsewhere along the margins of the Trias, as at Nottingham, that the characteristic pebbles prevail.

It is quite possible that the Bridgenorth conglomerate, or breccia, containing as it does local rocks, may have been partly of littoral origin; this breccia is sixty feet thick at Kidderminster.* The presence of local rocks is apparently common in the Midland Counties; and everywhere they are of more frequent occurrence in the marginal areas, although even there in some cases rare.

---

*Geology of England and Wales, II. Edit. (Woodward), p. 226.

Our information relating to the Trias of the Vale of Clwyd is at present meagre, such as it is I have given it to you.

It is to be hoped if any borings are put down in the Vale, that they will be under the supervision of competent Geologists, by which means we may get a more satisfactory knowledge of the base of the Trias, and the rocks it rests upon.

REPORT ON THE FIELD MEETING OF THE SOCIETY AT A SECTION IN THE MIDDLE COAL MEASURES, BETWEEN GARSWOOD AND ST. HELENS.

By J. J. Fitzpatrick.

On Saturday, May 21st, the Society visited an interesting section in the Middle Coal-measures, which was exposed in a cutting on the main line of the London and North-Western Railway, between Garswood Railway Station and St. Helens. Owing to an increase in the traffic with the coal district of Wigan, the Railway Company had found it necessary to widen the cutting, and this was done to the extent of adding two double lines of rails to those already laid down. This improve-

ment was effected throughout the whole of the distance between Wigan and St. Helens, and took place to the left of the cutting going from the former to the latter town.

The section extended from Garswood Railway Station for a distance of a mile and a quarter, ending about fifty yards from the last railway bridge, four of which span the cutting between the old Laffak and Garswood Colliery shaft and Garswood Station. From Garswood the cutting is made in a south-westerly direction towards St. Helens, and was opened out about twenty-four years ago. The section showed an alternating series of sandstones, shales, and coal-seams, having a dip to the south-east, varying from 7° to 12°. The beds exposed belong to the upper strata of the Middle Coal-measures. In the whole extent of the section there were twelve outcrops where the coal-seams were exposed, but owing to disturbance and dislocations, these were, no doubt, faulted and repeated portions of the same beds.

The following was found to be the thickness of each important coal-seam—

The first, near Garswood Station, 40 yards to the south-west of the first railway bridge, with a dip of 7° to the south-east 2½ feet. The second, a quarter of a mile from Garswood, 4 feet; the third, half a mile, 5 feet; the fourth, near the third railway bridge, 2½ feet; the fifth, at an important fault, having a direction from south-east to north-west, 3 feet. At this exposure there was evidence of much faulting and disturbance of the strata, and on both sides of the cutting the coal-seam was curved and contorted by the upthrow of the main fault, which is called the Colt Shed Fault, and is a down-

throw to the north-east. This interesting exposure was 60 yards to the south-west of the third railway bridge.

About a mile from Garswood Station, half-way between the third and fourth railway bridges, there was seen the most interesting exposure in the whole of the section. This seam, the sixth of importance, dipped 10° to the south-east, and could be traced from the bottom to the top of the section, which was here about forty feet in height. The value of this seam, which measured 5 feet, appeared to be fully appreciated by the contractor, as he had worked it at the surface to a considerable extent, the coal having been used for the work carried on in the widening of the cutting.

Resting upon this seam there was a bed of stiff light-brown clay, 4½ feet in thickness, which, near the highest part of the section, became soft and plastic like Boulder Clay. Underlying the seam there was a bed of underclay, or "warrant," four feet in thickness, containing nodules of ironstone.

The seventh seam was about 100 yards to the north-east of the fourth, and last railway bridge, and a mile and a quarter from the starting point at Garswood. This seam was 6 feet, but only 4 feet appeared to be workable coal, the lower part of the seam being inferior and shaly. During one of my visits I found the men working the seam, the coal being for the use of the contractor.

Occasionally a coal-seam rested upon the usual bed of underclay or "warrant." These beds varied in thickness, and some were traversed by roots.

Besides the fault already mentioned, there is another of importance having a direction from south-

east to north-west, with a downthrow to the south-west. This is called the Bullstake Fault, and is a little more than half a mile from Garswood Station.

At the second railway bridge the Coal-measures disappeared for a time. Abutting on this bridge, which is situated at the highest part of the railway line, there was a deposit of Boulder Clay, 18 feet in thickness, containing weathered fragments of granite and greenstone. This clay could be traced along the cutting for a distance of 120 yards, when an exposure of fine siliceous sand 30 yards in length was seen. The sand gradually became mixed with gravel, and assumed a coarser grain. This deposit of sand and gravel could be followed for a distance of 160 yards, near to that part of the cutting which is crossed by the Bullstake Fault, and where the Coal-measures again appeared. The clay was used for brick-making, by the contractor, and the sand for mixing mortar. The average height of this exposure of Boulder Clay, sand, and gravel, was 7 feet.

At the north-east side of the third railway bridge, to the right of the cutting going towards St. Helens, and just abutting on the lower part of the bridge, there was a bed of blue fossiliferous shale, 3 feet in thickness, containing nodules of ironstone.

Characteristic Coal-measure fossils including *Sigillaria*, *Lepidodendron*, *Calamites* and ferns were obtained, and a *Calamite*, found by Mr. Lomas, had the rootlets in an admirable state of preservation.

The Society had the advantage of the presence and advice of my friend, Mr. E. J. Grimshaw, mining engineer, of St. Helens, who, more than thirty years ago assisted Professor Hull with valuable information in making the original survey of the district, and who is

specially thanked by the Professor in the first and second editions of the memoir of the Geological survey referring to the geology of the country around Wigan and St. Helens, printed in 1860 and 1862 respectively.

Soon after examining the section with the Society, I again visited it with Mr. G. H. Morton, F.G.S., who was from home when the field meeting took place, and he has made a note of the chief features of the section in his new edition of the "Geology of the country around Liverpool"

The whole of the section exposed is known as the Ravenhead Section, in the St. Helen's district, and correlates with the following seams in descending order at Wigan :—

Wigan	5 feet
,,	4 ,,
,,	9 ,,

The Ravenhead Higher Delf and Main Delf at St. Helens constitute one seam in the section at Garswood, and that is called the Main Delf in De Rance and Strahan's Geological Survey, vertical section, sheet 61, published August, 1876.

At this Field Meeting the members were afforded an opportunity of examining some highly interesting outcrops of coal-seams, at a time when the chief features could be studied to the best advantage, and under the most favourable conditions.

FAULTED AREAS IN THE COUNTRY AROUND LIVERPOOL.

By G. H. Morton, F.G.S.

In the recent edition of the "Geology of the Country around Liverpool," the faults in the Trias are described as nearly all running north and south, or a few degrees to the east and west of that direction. There are several areas where the faults are well known, and where the direction of each has been exactly ascertained. It has, however, been found impossible to connect the faults in these areas on a map over the intermediate ground in consequence of the covering of Boulder Clay, or the land being under cultivation, and in some places occupied with buildings.

The faulted areas are Hilbre Island and Hilbre Point, Bidston, Storeton, South-end of Liverpool, and the Centre of Liverpool. Each of these five areas is shown on a portion of the 6-inch Ordnance Map, though there is little resemblance to the same parts of the Maps of the Geological Survey. This difference is in consequence of the advantages that a local observer has in being continually in the district, and able to make constant observation, compared to a survey made by a geologist in a short time when only able to see such excavations as happen to be open at the time of his visit.

HILBRE ISLAND AND HILBRE POINT.

At Hilbre Island the faults have been carefully represented on the Map and the direction found to be N. & S., or a few degrees to the E. or W. of those points, but one fault, and that the most important, is

N. 22° W. The faults at Hilbre Point vary from N. 10° E. to N. 22° E., but there is one that runs N. & S. None of these faults are shown on the Maps of the Geological Survey. At both these places the faults cross the strata diagonally, while in other areas they are strike faults, or nearly parallel to that of the strata. On Grange Hill, West Kirby, there are about three faults, but only one is well exposed. They run N. & S., and are strike faults.

The difference between the relation of the faults and the strike of the strata at Hilbre Point, compared with Grange Hill, confirms the conclusion that a considerable fault runs N. & S. along the coast of the River Dee. The change is in the strike of the strata, for the general direction of the faults is nearly the same in both places.

BIDSTON HILL.

At Bidston and Flaybrick Hills there are five faults, running N. & S., or a little to the E. of N., and they are all strike faults. Four of these are exposed, and the fifth, the only one shown on the Geological Survey Map, is obvious from the position of the base of the Keuper Sandstone on each side, and is shown by the contour of the ground.

STORETON HILL.

At the Storeton Quarries 22 faults are exposed. Of these 17 run N. & S., and 5 others are E. & W., being cross faults which merely run from one N. & S. fault to another. Some of the principal faults may be seen in several places, and although they appear to continue in a north and south direction, it is probable that they gradually run into each other at no great distance.

SOUTH END OF LIVERPOOL.

At the south-end of Liverpool, close to the Docks, and from the shore in front of the Dingle, the ground

rises abruptly from the river, and the 9 faults shown on the Map have been frequently exposed, and some of them may still be seen. Six of these are on the 6-inch Map of the Geological Survey. These faults run N. & S., N. 10° E., and N. 10° W. Several were visible for 300 yards during the construction of the graving docks, which are cut through 4 of them. These faults were more fully exposed than any others have been.

CENTRE OF LIVERPOOL.

Numerous faults have been exposed along the east of Liverpool in various places during the excavations for railways and buildings. Several faults occur between Hardman-street and Parliament-street, and another series crossed by the London and North-Western Railway. The direction of the faults varies from due N. & S. to N. 10° and 20° E. and W., but as they can seldom be seen in two places, the exact line of dislocation is often doubtful, and hence the difficulty of connecting one fault with another on the Map. The most important faults, those forming the boundaries between the subdivisions of the Bunter and Keuper formations, are very nearly ascertained.

The great number of the faults that traverse the strata beneath the City much increases the difficulty of correlation. If there were fewer faults it would be much easier to find the continuation of one into another, but the uncertainty is at present so great that years of patient observation will be required before a correct map, showing all the faults in the strata under Liverpool can be drawn.

As it is in contemplation to publish a map showing the faults as far as known in the areas referred to, further details are withheld for the present.

LIST OF WORKS AND PAPERS ON THE GEOLOGY OF THE COUNTRY AROUND LIVERPOOL, FROM JUNE, 1881, TO SEPTEMBER, 1890, WITH SOME ADDITIONS TO THE FORMER LISTS.

By G. H. Morton, F.G.S.

The following List of Works and Papers form a Second Supplement to "The Progress of Geological Research in connection with the Geology of the Country around Liverpool," or two Annual Addresses delivered to the Liverpool Geological Society in 1869-70. The "First Supplement" is printed in the "Proceedings," Vol. IV., p. 237. A few omissions precede the present List, as in the former Supplement.

1869.

Hull, E., M.A., F.R.S.—"The Trias and Permian Rocks of the Midland Counties of England."—*Memoirs of the Geological Survey of England and Wales.*

Contains references to the Permian, Bunter, and Keuper formations in Lancashire, and full descriptions of the two latter in many parts of Cheshire.

1875.

Potter, C.—"Observations on the Geology and Archæology of the Cheshire Shore."—*Trans. Hist. Soc of Lancashire and Cheshire.* Sec. 3, Vol. IV., p. 121.

Describes the Post-Glacial beds in succession, from the Boulder Clay upwards, including the Lower and Upper Forest beds. Refers to the laminated structure of the Scrobicularia clay on the west, and gives a section of the beds exposed at the east end of the Embankment. About Dove Point coins found belonging to the reigns of Edward the I.,

II. and III. are most numerous, but few of the time of Elizabeth. Norman, Saxon and Roman coins, with objects of the Stone age are also found. Considers that some catastrophe occurred at the close of the 14th century, and that the greatest number of the antiquities appertain to the 13th century, as stated by the late Dr. Hume. Average waste of the coast 3 yards in each year.

1878.

WALKER, A. O., F.L.S.—"Notes on the Lower Coal Measures between Bagilt and Holywell."—*Proc. Chester Soc. Nat. Science*, No. 2, p. 9.

Description of a series of thin shales, containing two beds of aluminous limestone, known as "cement stone," and worked close to Holywell. Both shales and limestone contain remains of shells and plants.

1881.

ROBERTS, I., F.G.S.—"Notes on the Strata and Water-level at Maghull."—*Proc. L'pool Geol. Soc.*, Vol. IV., p. 233.

Remarks on the variation of level, temperature, degrees of hardness, and analysis of water from the Upper Bunter Sandstone.

1881.

READE, T. M., C.E., F.G.S.—"On a Section of the Formby and Leasowe Marine Beds and superior Peat Beds, disclosed by the Cuttings for the Outlet Sewer at Hightown."—*Proc. L'pool Geol. Soc.*, Vol. IV., p. 269.

1881.

MOORE, T. J., C.M.Z.S.L.—"Notes on the Mammalian Remains from Hightown."—*Proc. L'pool Geol. Soc.*, Vol. IV., p. 277.

Description of bones and teeth of animals, found by Mr. Reade and described in the foregoing paper.

1881.

STRAHAN, A., M.A., F.G.S.—"On the Lower Keuper Sandstone of Cheshire."—*Geol. Mag.*, Vol. XVIII., p. 396.

Describes the Waterstones at Runcorn and Frodsham, and the relation of the subdivision to the Keuper Sandstone below, and the Red Marl above, and to the frequent absence of the Waterstones in S. W. Lancashire. The upper beds of the Keuper Sandstones at Frodsham are

not to be distinguished from the Upper Bunter. The rapid variation of colour in the Keuper Sandstone is also referred to. Refers to the break at the base of the Keuper Sandstone, which is over-estimated, and that the base of the Waterstones may be a more important stratigraphical* horizon in the Trias.

1881.

STRAHAN, A., M.A., F.G.S.—"On the Discovery of Coal-measures under the New Red Sandstone, and the so-called Permian rocks of St. Helens."—*Geol. Mag.*, Vol. XVIII., p. 433.

Gives sections, including the so-called Permian at several places in South-West Lancashire. Describes the Upper Coal-measures with the well-known red staining. Describes the bands of limestone found at Farnworth, Winwick, and Ardwick, near Manchester, and the occurrence of *Microconchus carbonarius* in that of the two last-named localities, and concludes that they all belong to the Upper Coal-measures, and that the presence of these upper measures under the Trias, will prevent the district being profitably worked for coal for many years to come.†

1881.

STRAHAN, A., M.A., F.G.S.—"On the Discovery of Coal-measures under New Red Sandstone, and on the so-called Permain Rocks of St. Helens, Lancashire."—*Rep. Brit. Assoc.*, Vol. LI., p. 632.

1882.

MORTON, G. H., F.G.S.—"The Base of the New Red Sandstone in the Country around Liverpool."—*Proc. L'pool Geol. Soc.*, Vol. IV., p. 321.

Contains an exhaustive enquiry into the presence of Permian strata in South-west Lancashire, in connection with the Lower Mottled Sandstone, with numerous sections of the strata some miles to the east of Liverpool.

1882.

MACKINTOSH, D., F.G.S.—"On the Post-tertiary changes of Level around the Coast of England and

---

* Letters on this Paper from E. Wilson, p. 523; A. Strahan, p. 574.

† Letters on this Paper from C. E. de Rance, p. 526; T. M. Reade, p. 572; E. Hall, Vol. XIX., p. 491; A. Irving, p. 559; C. E. de Rance, p. 575; A. Strahan, p. 48 and 576.

Wales." (Presidential Address).—*Proc. L'pool Geol. Soc.*, Vol. IV., p. 349.

Contains notice of Submerged Forest north of Parkgate, High-level Drifts on Halkin and Minera Mountains, but mostly relates to distant parts of England and Wales.

1882.

MORTON, G. H., F.G.S.—"Description of a Geological Map of the Storeton Quarries, Cheshire."—*Proc. L'pool Geol. Soc.*, Vol. IV., p. 406.

The Map was a portion of the 25-inch Ordnance Map, geologically coloured to show the Upper Bunter, Keuper Sandstone and Red Marl. Twenty-two faults were shown, nearly all being north and south. The out-crop of the "footprint bed" was also shown on the Map, which has not been published.

1882.

STRAHAN, A., M.A., F.G.S.—"The Geology of the Country around Prescot, Lancashire."—*Memoirs of the Geological Survey of England and Wales.*

The "Third Edition," with revised description of the Coal-measures, Trias, and Glacial deposits. An account of the Peat and Submerged Forest-beds, and chapters on Economic Geology and Water supply are given. An Appendix gives all recent information on the Coal-measures under the Trias, including several important sections in the neighbourhood. There is an exhaustive description of the Keuper Sandstone and Red Marl about Runcorn and Frodsham.

1882.

STRAHAN, A., M.A., F.G.S.—"The Geology of the neighbourhood of Chester."—*Memoirs of the Geological Survey of England and Wales.*

Gives a section and description of the Keuper Sandstone at Helsby Hill, near Frodsham. Full account of the Glacial-Sands, Gravels, and Upper Boulder Clay, with lists of the fossils. A List of Books, Papers, &c., on the district, by Mr. William Whitaker, B.A., F.G.S., forms an "Appendix."

1882.

READE, T. M., C.E., F.G.S.—"The Drift-beds of the North-West of England and North Wales.

Part II.: Their Nature, Stratigraphy and Distribution."—*Quar. Jour. Geol. Soc.*, Vol. XXXIX., p. 83.

Sections of the Boulder-clay are described, at the Atlantic Docks, Liverpool; Garston; and at Dawpool on the Dee, but many others in the North of England and Wales form a considerable portion of the Paper. The so-called Low-level Boulder-clay is synonymous with the Boulder-clay of other observers, and no reference is made to a High-level Boulder-clay. The usual separation into Upper and Lower Boulder-clay is not recognised, but that the formation is made up of two or more subdivisions is evident from the numerous woodcuts which illustrate the Paper. Considers that there is no reason for supposing the Boulder-clay can be separated into subdivisions indicating anything beyond local conditions, which caused different lithological characters. A Map of the area described and a list of Invertebrata found in the Boulder-clay given.

1883.

MORTON, G. H., F.G.S.—"Section across the Trias, recently exposed in a Railway Excavation in Liverpool."—*Proc. L'pool Geol. Soc.*, Vol. IV., p. 427. *Rep. Brit. Assoc.*, Vol. LIII., p. 489. *Nature*, XXVIII., p. 578.

Description of a well exposed section along the railway from Lime-street to Edgehill Station, showing the Upper Pebble-beds, Upper Bunter and Keuper Sandstone, with the thickness of each. Twelve faults cross the section, and the throw of each is given. A lithographic plate accompanies the Paper.

1883.

MORTON, G. H., F.G.S.—"On the Strata between the Carboniferous Limestone and the Coal Measures in Denbighshire and Flintshire."—*Trans. Manchester Geol. Soc.*, Vol. XVII., p. 74.

Detailed description of the strata above the Carboniferous Limestone, probably representing the Yoredale, Millstone Grit and Lower Coal-measures, and collectively named the Cefn-y-Fedw Sandstone from the difficulty in correlating them with similar formations in Lancashire and Derbyshire. Several areas are described, and the strata are found to differ as much in Flintshire as between that County and the others referred to. The strata in the north of Flintshire are described.

1883.

MORTON, G. H., F.G.S.—"Permian and Trias of South-West Lancashire."—*Geol. Mag.*, Vol. XX., p. 95.

Describes a thickness of 200 feet of Marl, at Hunt's Cross, Woolton, beneath Boulder-clay, and supposes it to be Permian, or possibly Keuper Marl.

1883.

De Rance, C.E., F.G.S.—"Notes on Geological Sections, within forty miles Radius of Southport."—*Geol. Mag.*, Vol. XX, p. 500. *Rep. Brit. Assoc.*, Vol. LIII, p. 489.

General description of the formations within the area described, including those around Liverpool.

1883.

Reade, T. M., C.E., F.G.S.—"The Human Skull found near Southport."—*Geol. Mag.*, Vol. XX., p. 547.

Shows that the skull described at the meeting of the British Association meeting in that town, was not of the great antiquity Dr. Barron supposed; it having been found on an old land surface of peaty soil, and covered only by blown sand.

1883.

De Rance, C.E., F.G.S.—"Notes on the Post-Glacial Geology of the Country around Southport."—*Nature*, Vol. XXVIII., p. 490.

1884.

Reade, T. M., C.E., F.G.S.—"Experiments on the Circulation of Water in Sandstone."—*Proc. L'pool Geol. Soc.*, Vol. IV., p. 434.

1884.

Ricketts, C., M.D., F.G.S.—"On Indented Pebbles in the Bunter Sandstone, near Prescot."—*Proc. L'pool Geol. Soc.*, Vol. IV., p. 447.

Describes indented pebbles in a thin conglomerate in the Pebble-beds at Twist's Quarry, Holt Lane, Prescot.

1884.

Shone, W., F.G.S.—"The Silting up of the Dee: Its Cause."—*Proc. Chester Soc. Nat. Science*, No. 3, p. 52.

Contains remarks on the geological history of the Dee and the silting up of the Estuary, with information respecting the rise and fall of the tides.

1884.

Geological Survey Maps.—"*Quarter Sheets.*" New Editions of most of those around Liverpool were published about this year, and new Maps of the Superficial Geology. There are now two sets of Maps, one showing the solid geology, and the other the drift. The following are those of the country around Liverpool: 79 N.W., N.E., S.W. and S.E., 80 N.W., 89 S.W. and 90 S.E.

1884.

Reade, T. M., C.E., F.G.S.—"Ripple marks in Drift in Shropshire and Cheshire."—*Quar. Jour. Geol. Soc,,* Vol. XL., p. 267.

Describes ripple-marks in sand covered with Boulder-clay, at Tranmere, Cheshire. Shells were found in the sand, and a list is given. Could not call to mind any previous notice of them*

1884.

Reade, T. M., C.E., F.G.S.—"Further notes on Rock Fragments from the South of Scotland, imbedded in the Low-level Boulder Clay of Lancashire."—*Quar. Jour. Geol. Soc.,* Vol. XL., p. 270.

1884.

Hicks, H., M.D., F.G.S.—"On some Recent Researches in Bone-Caves in North Wales."—*Proc. Geologists' Assoc.,* Vol. IX., p. 1.

This Paper contains the first accounts of Ffynnon Beuno and Cae Gwyn Caves, and a woodcut of the entrance to the former before either was worked.

1884.

Reade, T. M., F.G.S.—"On a Section of Keuper Marls at Great Crosby."—*Geol. Mag.,* Vol. XXI., p. 445.

1884.

Strahan, A., M.A., F.G.S.—"The Geology of Cheshire."—*Jour. Iron and Steel Institute,* for 1884, p. 352.

*** Ripple-marks in sand with shells under Boulder-clay, were described in 1863, in the "Geology of Liverpool," p. 42.**

Relates principally to Cheshire and the deposits of salt in the Red Marl, but the Millstone Grit, Coal-measures, Bunter, Keuper and the Drift in the country around Liverpool are referred to, and much information given with regard to the Coal-measures.

1885.

MORTON, G. H., F.G.S.—"The Microscopic Character of the Triassic Sandstones of the Country around Liverpool."—*Proc. L'pool Geol. Soc.*, Vol. V., p. 52.

Contains a brief history of the examination of sands and sandstones, and a minute description of those forming the subdivisions of the Bunter and Keuper of the country around Liverpool.

1885.

READE, T. M., C.E., F.G.S.—"The Mersey Tunnel: Its Geological Aspects and Results."—*Proc. L'pool. Geol. Soc.*, Vol. V., p. 74.

Describes the Pebble-beds and overlying Boulder-clay found under the bed of the Mersey. Remarks on the pre-glacial channel of the Mersey.

1885.

BEASLEY, H. C.—"A Quarry at Poulton, and the Relation of the Glacial Markings there, to others in the neighbourhood."—*Proc. L'pool. Geol. Soc.*, Vol. V., p. 84.

Additional instances of striation on the surface of the rock by ice, at Wallasey and Flaybrick Hill, with the usual details.

1885.

READE, T. M., C.E., F.G.S.—"Borings on the Southport and Cheshire Extension Railway."—*Proc. L'pool Geol. Soc.*, Vol V., p. 93.

Gives a series of borings taken at various points along the railway.

1885.

READE, T. M., C.E., F.G.S.—"On a Section across the River Douglass, at Hesketh Bank. A Post-Glacial Deposit in which were Human Bones."—*Proc. L'pool Geol. Soc.*, Vol. V., p. 100.

Human bones found in "Recent silts," and which the author assumes to be "of considerable age."

1885.

Beasley, H. C.—"A section of the Upper Keuper at Oxton."—*Proc. L'pool Geol. Soc.*, Vol. V., p. 134.

Describes the small exposure of Red Marl at Oxton. Pseudomorphic crystals of Chloride of Sodium, dendritic and ripple-marks of frequent occurrence.

1885.

Reade, T. M., C.E., F.G.S.—"Notes on a Bed of Fresh-water Shells and a Chipped Flint from the Alt Mouth."—*Proc. L'pool Geol. Soc.*, Vol. V., p. 137.

Describes worked flints and bones found in the Post-glacial deposits at the Alt Mouth. Also, a supposed Roman needle, bronze key, and remains of horse and red deer.

1885.

Strahan, A., M.A., F.G.S.—"The Geology of the Coasts adjoining Rhyl, Abergele and Colwyn."—*Memoirs of the Geological Survey of England and Wales.*

Contains description of the Carboniferous Limestone, Millstone Grit and Lower Coal-measures of the north of Flintshire, and lists of the fossils by G. H. Morton, F.G.S. The Glacial and Post-Glacial beds are described. The Mines and minerals are given, and a list of Works on the Geology of Denbighshire and Flintshire.

1885.

Reade, T. M., C.E., F.G.S.—"Evidences of the action of Land-ice at Great Crosby, Lancashire."—*Quar. Jour. Geol. Soc.*, Vol. XLI., p. 454.

Describes a bed of disturbed marl containing small fragments and large blocks of sandstone, supposed to be the result of land-ice. A woodcut shows the Red Marl, with the disturbed bed 3 or 4 feet thick resting on it, and the whole covered with Boulder-clay.

1885.

Ricketts, C., M.D., F.G.S.—"On some Erratics in the Boulder Clay of Cheshire, &c., and the Conditions of Climate they denote."—*Quar. Jour. Geol. Soc.*, Vol. XLI., p. 591.

States that glacial phenomena in the Valley of the Mersey indicate that the country was covered with ice and snow during the Glacial period. Considers that the clay, stones and boulders, all lead to this

conclusion, and relies much on weathered stones found in the Boulder-clay, and which are minutely described with the aid of woodcuts.

1885.

HICKS, H., M.D., F.R.S.—"On the Ffynnon Beuno and Cae Gwyn Bone Caves."—*Geol. Mag.*, Vol. XXII., p. 510.

Contains a description of both the caves, and a list of Mammalian remains that were found in Ffynnon Beuno Cave, comparatively few having been found in Cae Gwyn Cave. Some flint flakes of human workmanship were discovered in both caves.

1885.

HICKS, H., M.D., F.R.S.—"On the Ffynnon Beuno and Cae Gwyn Bone-Caves, North Wales."—*Rep. Brit. Assoc.*, Vol. LV., p. 1021.

Contains a description of the Caves and Mammalian remains found in them.

1886.

HEWITT, W., B.Sc.—"Notes on the Topography of Liverpool."—*Proc. L'pool Geol. Soc.*, Vol. V., p. 145.

Describes the surface changes that have taken place in and about Liverpool during local historic times, illustrated by a topographical relief model of the district, constructed by the author, and exhibited at the meeting.

1886.

READE, T. M., C.E., F.G.S.—"On a Section of the Trias at Vyrnwy-street, Everton, displaying Evidence of Lateral Pressure."—*Proc. L'pool Geol. Soc.*, Vol. V., p. 158.

Describes contorted surface of Bunter Sandstone, due to rock movement before the denudation of Triassic beds.

1886.

RICKETTS, C., M.D., F.G.S.—"On Footprints and Plants in the Trias at Oxton Heath."—*Proc. L'pool Geol. Soc.*, Vol. V., p. 168.

Describes footprints of *Rhynchosaurus*, and supposed leaves from the Keuper Sandstone at Oxton.

1886.

STRAHAN, A., M.A., F.G.S.—"On the Glaciation of South Lancashire, Cheshire, and the Welsh Border."—*Quar. Jour. Geol. Soc.*, Vol. XLII., p. 369.

Fully describes the Glacial striæ, and gives diagrams showing the direction in South Lancashire, Cheshire, and the Welsh border. The difference in the direction between the two areas is remarkable, and accompanied by a corresponding change in the transportation of the drift. Refers to the stratified condition of the Boulder-clay and sands in well-exposed sections, and to the striæ being only found under the uppermost or newest member of the Boulder-clay. That the striæ were covered immediately after being produced—during the deposition of the Upper Boulder-clay. Along the Welsh border a Lower Boulder-clay, or "Till" seems to be the product of an ice-sheet; though the striated areas described have no connection with this earlier deposit.

1886.

Hicks, H., M.D., F.R.S.—"On Some Further Researches in Bone-Caves in North Wales."—*Proc. Geologists' Assoc.*, Vol. X., p. 14.

Additional observations on the Ffynnon Beuno and Cae-Gwyn Caves.

1886.

Hughes, T. McKenny, M.A., F.R.S.—"On the Ffynnon Beuno Caves."—*Geol. Mag.*, Vol. XXIII., p. 489.

Recognises four drifts in the Vale of Clwyd, and describes them in relation to the deposits in and about the caves. Concludes that the caves are of Post-Glacial age, from the palæontological evidence, and from the condition and deposits at the entrance to the Cae-Gwyn Cave.

1886.

Hicks, H., M.D., F.R.S.—"On the Ffynnon Beuno and Cae Gwyn Caves."—*Geol. Mag.*, Vol. XXIII. p. 566.

Substance of the Report to the British Association on the explorations of the Caves. Woodcut sections of the entrance and interior of the Cae Gwyn Cave are given. Describes the finding of a well-worked flint-flake, as dug up from the bone-earth on the south side of the entrance. A list of the animal remains as defined by Mr. W. Davies, F.G.S., is given, and contains 11 genera and 16 species.

1886.

"Report of the Committee, appointed for the purpose of exploring the Caves of North Wales."—*Rep. Brit. Assoc.*, Vol. LVI., p. 219.

Full report on the Caves. Woodcuts showing deposits both inside and outside the entrance to Cae Gwyn Cave. List of the Mammalian remains, by Mr. W. Davies, F.G.S.

1886.

Morton, G. H., F.G.S.—"On the Carboniferous Limestone of the North of Flintshire."—*Rep. Brit. Assoc.*, Vol. LVI., p. 673.

Describes the four subdivisions of the Limestone as exposed from Castell Prestatyn to Woel Hiraddug.

1886.

Morton, G. H., F.G.S.—"Carboniferous Limestone of the North of Flintshire."—*Proc. L'pool. Geol. Soc.*, Vol. V., p. 169.

Describes the four subdivisions of the Carboniferous Limestone, as exposed from Castell Prestatyn to Moel Hiraddug, and gives a list of the fossils. A lithographic section shows each subdivision and the Red basement-bed.

1886.

Hicks, H., M.D., F.R.S.—"Evidences of Man and Pleistocene Animals in North Wales prior to the Glacial Deposits."—*Nature*, Vol. XXXIV., p. 216.

1886.

Gasking, Rev. S., F.G.S.—"The Geology of St. Helens."—*Proc. Isle of Man Nat. Hist. and Antiq. Soc.*

Describes the Lower, Middle and Upper Coal-measures, Permian, Trias and the Drift deposits which cover the strata around St. Helens.

1886.

Morton, G.H., F.G.S.—"Note on the Carboniferous Fishes of North Wales."—*Proc. L'pool Geol. Soc.*, Vol. V., p. 243.

Gives a list of all the species determined by Mr. W. Davies, F.G.S.

1887.

Beasley, H. C.—"Some Instances of Horizontally Striated Slickensides."—*Proc. L'pool Geol. Soc.*, Vol. V., p. 246.

Description of joints, with horizontally striated surfaces, indicating slight faulting.

1887.

Jeffs, O. W.—"The Calday-Grange Fault, West Kirby."—*Proc. L'pool Geol. Soc.*, Vol. V., p. 247.

Description of the fault between the Bunter and Keuper Sandstones, which was remarkably well exposed, illustrated by a photograph.

1887.

MORTON, G.H., F.G.S.—"The Microscopic Characters of the Cefn-y-Fedw Sandstone of Denbighshire and Flintshire."

MORTON, G. H., F.G.S.—The Microscopic Characters of the Millstone Grit of South-West Lancashire."—*Proc. L'pool Geol. Soc.*, Vol. V., pp. 271 and 280.

1887.

MORTON, G. H., F.G.S.—"Local Historical, Post-Glacial and Pre-Glacial Geology." (Presidential Address).—*Proc. L'pool Geol. Soc.*, Vol. V., p. 303.

Describes the changes in the contour of the ground on which Liverpool is built, during the last forty or fifty years, and the still greater changes that have altered the surrounding country, and formed the Estuary of the Mersey during recent geological times. The recent fauna of the Post-Glacial deposits is shown by a list of the Mammalian remains found in them. The deundation of the Boulder-clay considered to be insignificant, the deposit having formed an undulating covering of no great thickness at the close of the Glacial period. The Pre-Glacial caves at Tremeirchion, near St. Asaph, are described, and a list of the Mammalian remains given.

1887.

MORTON, G. H., F.G.S.—"Stanlow, Ince, and Frodsham Marshes."—*Proc. L'pool Geol. Soc.*, Vol. V., p. 349.

Presents a description of the river boundary of these Marshes before the excavations for the Manchester Ship Canal began. From historical accounts of great floods in the neighbourhood of Stanlow Abbey, and an old land surface below a thick deposit of esturine silt, it is assumed that the latter had been deposited during the last 600 years.

1887.

RICKETTS, C., M.D., F.G.S.—"Report of Excursion along Mersey Tunnel Extension and Wirral Railway."—*Proc. L'pool Geol. Soc.*, Vol. V., p. 388.

After referring to subsidences from the running out of sand between the Boulder-clay and the rock beneath, beds of sand associated

with, and overlying the Boulder-clay are described. This upper sand appeared to have been deposited in a channel in the Boulder-clay which had processes overlying and projecting over the sand. A lower bed of sand and gravel, with fragments of shells was observed, but no list of the latter is given.

1887.

Reade, T. M., C.E., F.G.S.—"Report of the Field Meeting at Hilbre Island."—*Proc. L'pool Geol. Soc.*, Vol. V., page 389.

Refers to soft red sandstone (Bunter), a conglomerate bed which appears made up of the Triassic beds below, with a sandstone resembling the Cheshire Keuper above. In addition to Triassic sandstone pebbles, the conglomerate contained some of quartzite.

1887.

Beasley, H. C.—"Report of Field Meeting at Wallasey."—*Proc. L'pool Geol. Soc.*, Vol. V., p. 389.

Refers to horizontal faults, slickensides and joints. A conglomerate bed of marl, supposed to be connected with lateral movement of the rock, near the base of the Keuper Sandstone, is also described.

1887.

Hewitt, W., B.Sc.—"Report of Field Meeting at Runcorn."—*Proc. L'pool Geol. Soc.*, Vol. V., p. 390.

Mr. C. Timmins, of Runcorn, conducted the members, and pointed out where the Keuper Marl rested on the Keuper Sandstone, and the fault crossing the railway throwing down the Red Marl against the Keuper Sandstone. Keuper Sandstone consists of both hard and soft sandstone. No footprints were found to occur.

1887.

Gasking, S., B.A.—"Report of Field Meeting at St. Helens."—*Proc. L'pool Geol. Soc.*, Vol. V., p. 591.

Describes visit to the Middle Productive Coal-measures at Doulton's Delph, between the Flaggy Delf Coal and the Rushy Park Coal, and gives generic names of several coal-plants that occur there. The trunk of a tree was seen in situ, and specimens of *Anthracosia acuta* abundant.

1887.

Morton, G. H., F.G.S.—"On the Discovery of Sponge Spicules in the Chert Beds of Flintshire."—*Proc. L'pool Biol, Soc.*, Vol. I., p. 69.

1887.

NEWTON, E. T., F.G.S.—"The Ffynnon Beuno Cave."—*Geol. Mag.*, Vol. XXIV., p. 94.

A letter referring to the absence of characteristic Pre-Glacial species in the Ffynnon Beuno Cave, and that the Mammalian fauna indicate a Pleistocene and not a Pre-Glacial origin.

1887.

HICKS, H., M.D., F.R.S.—"The Faunas of the Ffynnon Beuno Caves and the Norfolk Forest Bed."—*Geol. Mag.*, Vol. XXIV., p. 105.

A reply to Mr. Newton's letter. The caves being covered with Glacial deposits, it is clear that the Mammalian remains they contain are Pre-Glacial, even though they indicate a Pleistocene age.

1887.

MORTON, G. H., F.G.S.—"The Carboniferous Limestone of North Flintshire."—*Geol. Mag.*, Vol. XXIV., p. 120.

Gives the subdivisions of the formation as shown in the precipitous out-crop between Prestatyn and Meliden, and a concise description of each.

1887.

HICKS, H., M.D., F.G.S.—"Second Report on Cae Gwyn Cave."—*Geol. Mag.*, Vol. XXIV., p. 471.

Describes the beds of Boulder-clay, sand, and bone-earth outside the entrance to the cave. A list is given of the shells, and the rocks forming the boulders in the clay.

1887.

"Second Report of the Committee for exploring Cae Gwyn Cave, North Wales."—*Rep. Brit. Assoc.*, Vol. LVII., p. 301.

Describes extended excavation in front of the Cave, and gives a list of shells from the Boulder-clay above the entrance. A list of rocks forming boulders in the clay is also given.

1887-8.

"The Ffynnon Beuno and Cae Gwyn Caves."—*Nature*, Vol. XXXVII. Letters by Brown, A. J. Jukes, p. 224; Hicks, H., M.D., F.R.S., pp. 129, 202; Morton, G. H., F.G.S., p. 32; Smith, Worthington G., pp. 7, 105, 178.

1888.

Beasley, H. C.—"Some irregularly Striated Joints in the Keuper Sandstone of Lingdale Quarry."—*Proc. L'pool Geol. Soc.*, Vol. V., p. 386.

Describes and gives direction of several small faults or joints, with the aid of a lithographic plate.

1888.

Beasley, H. C.—"President's Address."—*Proc. L'pool Geol. Soc.*, Vol. VI., p. 11.

Observations on the Glacial deposits and the striated surfaces of the underlying rocks. General remarks on the Trias and its sub-division, the junction of the Bunter and Keuper Sandstone, and the character of the sand of which they are composed. Reference is also made to the pebbles contained in the Bunter and Keuper; to the frequency of current-bedding, and the probable conditions under which the strata were formed.

1888.

Picton, Sir J. A., F.S.A.—"Local Historical Changes on the Surface of the Land in and about Liverpool."—*Proc. L'pool Geol. Soc.*, Vol. VI., p. 31.

Describes the great alteration made in the surface during the growth of Liverpool, and gives many instances of the levelling of the ground. Shows how the aspect of the surrounding country has been changed by the obliteration of numerous water-courses, which formerly flowed into the Mersey. The gradual silting up of the Dee, and the waste of the coast of Wirral are described.

1888.

Morton, G. H.—"Further Notes on the Stanlow, Ince, and Frodsham Marshes."—*Proc. L'pool Geol. Soc.*, Vol. VI., p. 50.

Continuation of former paper on the subject, with additions and corrections after the excavation of the Manchester Ship Canal began. Further details respecting the site of Stanlow Abbey. Deposition of the Estuarine Silt supposed to have been at the average rate of one foot in 100 years. Sections of the Post-Glacial and Recent beds along the canal are given, and additional information promised during the progress of the work.

1888.

Potter, C.—"Antiquities of the Meols Shore."—*Trans. Hist. Soc. of Lancashire and Cheshire*, Vol. XL., p. 143.

Supposes that the deposition of the "Scrobicularia bed" was in very early Palæolithic times. Describes the trees in the old forest beds as associated with peat and plants of lacustrine growth, and refers to the trees having been transported into the peat in the state in which they are now found, whilst the peat was forming. Refers to evidence of man's handiwork extending from the early Neolithic period to late Norman. Concludes with reference to the supposed catastrophe in the Norman period, and states that "In the lapse of time man again appears on the scene."

1888.

Reade, T. M., C.E., F.G.S.,—"An estimate of Post-Glacial Time."—*Quar. Jour. Geol. Soc.*, Vol. XLIV, p. 291.

Assumes the valley of the Dee and Mersey were filled with Boulder-clay towards the close of the Glacial period, and that it has been greatly denuded. The Post-Glacial deposits are supposed to extend from a very remote period of time. The Drift-sand fringing the coast is supposed to date from Pre-Historic times. From various data it is concluded, that the denudation of the Boulder-clay occupied 40,000 years, the formation of the Post-Glacial deposits, 15,000 years, and the Drift-sand, 2,500 years; being 57,500 years as the measure of recent geological time for the area around Liverpool.

1889.

Timmins, A., C.E.—"Notes on a few Borings, and the Base of the New Red Sandstone in the neighbourhood of Liverpool."—*Proc. L'pool. Geol. Soc.*, Vol. VI., p. 56.

Details of many recent borings. Is of the same opinion as Mr. G. H. Morton, that Red Marl begins the Permian strata, and does not consider that the Lower Mottled Sandstone occurs in the borings at the east of Liverpool. Gives analyses of probable Permian marls and sandstones, containing a large proportion of carbonate of lime.

1889.

Reade, T. M., C.E., F.G.S.—"Slickensides and Normal Faults."—*Proc. L'pool Geol. Soc.*, Vol. VI., p. 92.

Describes slickensides in faults in the Trias around Liverpool, Carboniferous and Silurian rocks, and the results of experiments proving them to have been produced by the fracture and grinding of

opposite sides of rock against each other. The cause of faults due to vertical movements, either up-throws or down-throws by a continuously acting force, caused by variations of temperature in the earth's crust.

1889.

MORTON, G. H., F.G.S.—"Some Faults exposed in Shafts and Borings in the Country around Liverpool." *Proc. L'pool Geol. Soc.*, Vol. VI., p. 115.

Contains an account of shafts and borings that have proved the position of faults, the thickness, and the depth of subdivisions of the Trias beneath the surface. Refers to the Whiston, Green Lane, Borough Road, and Flaybrick Water Works, and to the wells and borings connected with them, and faults near them.

1889.

BEASLEY, H. C.—"The Life of the English Trias." (Presidential Address).—*Proc. L'pool Geol. Soc.*, Vol. VI., p. 145.

Relates principally to the Trias generally, but refers to the Annelids, Footprints and Plants found in the neighbourhood of Liverpool.

1889.

BEASLEY, H. C.—"Field Meeting at Burton Point."—*Proc. L'pool Geol. Soc.*, Vol. VI., p. 216.

Contains a brief description of the Lower Pebble-beds, and the underlying Lower Soft Sandstone of the Bunter formation.

1889.

"Fifteenth Report of the Committee appointed for investigating the circulation of underground Waters."—*Rep. Brit. Assoc.*, Vol. LIX., p. 71.

Contains information collected by Mr. C. E. De Rance, F.G.S., and from Mr. A. Timmins, C.E., F.G.S., relating to borings around Liverpool.

1889.

KIDSTON, R., F.R.S.E., F.G.S.—"On the Fossil Plants in the Ravenhead Collection in the Free Library and Museum, Liverpool."—*Trans. Royal Soc., Edinburgh*, Vol. XXXV., p. 391.

KIDSTON, R., F.R.S.E., F.G.S.—"On some Fossil Plants from Teilia Quarry, Gwaenysgor, near Prestatyn, Flintshire."—*Trans. Royal Soc. Edinburgh*, Vol XXXV., p. 419.

Contains description of new, and lists of all the, species in both localities. The lists will be found in the "Geology of the Country around Liverpool," having been contributed by Mr. Kidston.

1889.

Reade, T. M., C.E., F.G.S.—"Saxicava Borings and Valves in a Boulder Clay Erratic."—*Nature*, XL., p. 246.

1890.

Reade, T. M., F.G.S.—"Note on a Boulder met with in driving a Sewer heading in Addison Street."—*Proc. L'pool. Geol. Soc.*, Vol. VI., p. 188.

Instance of a Boulder being found in the Boulder-clay, and buried in the underlying sandstone instead of removing or breaking it up.

1890.

Reade, T. M., C.E., F.G.S.—"Note on some Mammalian Bones found in the Blue Clay under the Peat and Forest-bed at the Alt mouth."—*Proc. L'pool. Geol. Soc.*, Vol. VI., p. 213.

Confirmation of conclusions as to the beds from which Mammalian bones previously described were obtained.

1890.

Strahan, A., M.A., F.G.S.—"The Geology of the neighbourhoods of Flint, Mold and Ruthin."—*Memoirs of the Geological Survey of England and Wales.*

Although relating principally to the country beyond a radius of 20 miles from Liverpool, the work contains frequent references to places within that distance. The Carboniferous Limestone, Millstone Grit, and Coal-measures about Holywell, the Bunter Sandstone at Burton Point and the Vale of Clwyd are described. Contains a full description of the Glacial drift, and striæ on the rock surfaces. The Pre-Glacial and Post-Glacial History of the Dee, with maps of the river at different dates are given, and the work concludes with an account of the metalliferous mines, and sections from cellieries and boreholes in the Flintshire Coal-field.

1890.

Morton, G. H., F.G.S.—"Notes on the Bunter and Keuper formations in the Country around Liverpool."—*Geol. Mag.*, Vol. XXVII., p. 497. *Rep. Brit. Assoc.*, Vol. LX., p. 819.

Gives thickness of the subdivisions of the Bunter and Keuper formations. Microscopic structure of the sandstone. Description of the pebbles in the Trias. Remarks on the conditions under which the strata were deposited.

1890.

MORTON, G. H., F.G.S.—"The Geology of the Country around Liverpool, including the North of Flintshire," 287 pp., and 35 Illustrations. George Philip and Son, London and Liverpool.

Although a Second Edition, it is a new and larger work, written with the intention of recording in a permanent form the observations of many years. It virtually includes all the papers written by the author on local geology, revised to the present time; and it presents a description of the geology of the country for about twenty miles around Liverpool. Lists of fossils from each formation are given, and some of those from the Trias and Post-Glacial deposits are figured. Some of the sections are plates and others are woodcuts. The work was published in January, 1891, but most of the pages were printed in 1890.

NOTES ON A SECTION OF THE TRIAS AND BOULDER CLAY IN CHAPEL STREET, LIVERPOOL.

By T. MELLARD READE, C.E., F.G.S., &c.

EXCAVATIONS on the site of Gruning & Co.'s buildings, in Chapel Street, in preparation for new premises, have disclosed a section of Boulder Clay, resting on Middle Bunter Sandstone, which possesses some points of interest well worth recording.

My attention was first called to this section by our member, Mr. O. W. Jeffs, and by Mr. Edward W. Cox, who had been making sketches and records as the excavation progressed, which have been kindly placed at my disposal.

The first feature that attracted attention was the presence of rotten greenstone boulders, at the base of the

Boulder Clay, which appeared as if pressed into the sandstone; six of them were recorded of the following dimensions on the fractured face, as they lay in the clay; the third dimension could not be obtained.

No. 1....	1 ft. 8 in. by 10 in.	Recorded by Mr. Cox, according to whose drawings they were less rounded than those that I saw. They lay in depressions in the rock, which was much shattered underneath.
„ 1A ..	1 ft. 6 in. by 1 ft.	
„ 2....	1 ft. 2 in. by 8 in.	
„ 3....	1 ft. 2 in. by 1 ft. 1 in.	Drawn and recorded by the Author.
„ 4....	8 in. by 6 in.	Recorded by Mr. Cox and Mr. Jeffs.
„ 5....	$4\frac{1}{2}$ in. by $2\frac{1}{2}$ in.	

The first time I took notes of the Boulder Clay section was on 4th February, 1891, Mr. Cox and Mr. Jeffs being present, although I had visited this excavation on a previous occasion, and had taken samples of the Triassic Sandstone. On this occasion, the boulder No. 2 was visible, measuring 1 ft. 2 in. by 8 in. on the face. It was decomposed in concentric laminæ, from the surface to the core, and of that yellowish green colour well known to those who examine the stony contents of our Boulder Clay. It lay in a depression of the rock, about five inches below the general surface, which was a a plane, slightly dipping to the south-west. The rock seemed quite hard underneath, and the surface of the boulder adhered so closely to the rock, that I was enabled to split off a junction specimen, showing the red rock and the decomposed greenstone adherent: this I exhibit. I also took a specimen of the Boulder Clay and greenstone adherent, which I also shew you.

Continuing the line of section to the north-east, along the then exposed face, a laminated bed of Boulder Clay and sand, about five inches thick, and very regular, extended a distance of about 30 feet. This bed seemed to be very general, lying directly on the rock.

In this seam was a boulder, or large pebble, of hard, Silurian grit, 5 in. by 6 in. by $3\frac{1}{2}$ in. On taking it out, I found the part resting on the rock was roughly fractured, with no signs of polishing or striations, but the rounded surface, which was uppermost, was irregularly rubbed and striated as you see. I took specimens of the coarser sand from the top of the 5-inch seam, which my son Aleyn washed and mounted for me.

Mr. Jeffs got a further specimen next day, and this was clayey, and of a finer grain; it was treated in the same way. I exhibit the washed sand, and also the micro slides. The sand is distinguished for the extreme rounding and polishing of a large proportion of the grains; some of these highly polished grains are selected and mounted separately. They were mostly of quartz, but one is of a black igneous rock; the grains are mostly flattened ellipsoids; they vary from $\frac{1}{30}$ of an inch to $\frac{1}{12}$ of an inch on the longer diameter. There are two slides of No. 1 specimen, and two of No. 2, marked respectively "coarse" and "fine." These grains have been separated into different average sizes by washing, and they both exhibit the characteristics of the stony contents of the Boulder Clay, though on a microscopic scale. There are well-rounded grains down to $\frac{1}{100}$ inch diameter, mixed with sub-angular grains, and distinct unrounded splinters of quartz. Some of the grains are evidently fragments of quartz crystals, while others have on their surface the secondary crystallized growths distinctive of sandstone grains. The grains are preponderatingly of quartz, but are mixed with grains of other minerals, shewing more or less signs of attrition. The slide, No. 1 coarse, gives a good idea of the varied character of the grains, as even the quartz varies very much. Mixed with all the sand are many minute

rounded fragments of shell; and the shell fragments were also to be clearly seen by the naked eye, both in the seam described, and distributed through the Boulder Clay above.

The bed of Boulder Clay above the seam was about four feet thick, being pretty stiff clay of the usual character known about here. The rest of the excavation above this was filled-up stuff, or else brickwork of the old buildings. I visited the excavations again on February 5th, with Mr. Jeffs, when another rotten greenstone boulder (No. 3) was to be seen. It was also in a depression in the rock, and embedded in Boulder Clay. The seam of laminated clay and sand curved gently and regularly over the top of the boulder, as shown in the section in a monoclinal curve, and above this was the Boulder Clay as before. At the top point of the boulder was a broken rounded pebble included in the sand seam, with the broken part resting against the boulder.

Our examination of the surface of the rock where it was not disintegrated into sand, in those places where it could be examined, showed a rough hard surface, with no evidence at all of planing or striation, in this respect differing from most other examples I have seen.

There was a strongly defined and very level line of demarcation between the Triassic rock and the Boulder Clay, which became more apparent towards the completion of the excavations. On the north side of the ground this line of junction was well seen.

Remains of old stone walling, resting on the Boulder Clay, forming the foundation of a house, was observed by Mr. Cox and Mr. Jeffs, and the former recognises it as 16th century work by ancient masons' tool marks.

The upper part of the Trias, on the west side, was divided by vertical fissures and faults of a few inches throw, widened by weathering.

General Observations.

The Boulder Clay belongs to the Low-level Boulder Clay and Sands series, and affords striking evidence of the marine character of that deposit. If we accept its marine origin, it will be difficult not to include the rotten decomposed boulders along with it. The depressions in the sandstone where they occurred, and in which they lay, remain to be accounted for.

The sandstone surrounding the bottom of the boulders, and to which they were attached, appeared to be of a softer character than much of the rock surface, and may have been reconsolidated sand worn from the rock itself, but on drying it has become very hard. The boulders bore no evidence of having been pushed along, and the surface of the rock shewed no glaciation. My impression is that these boulders have been dropped from floating ice on a shelving rocky shore, and have worn holes in the rock by rocking about, combined with the swirl of the water round them. Be that as it may, the bed of laminated sand and clay lying on the rock shows undoubted evidence of aqueous deposition, not only in the regularly laminated character it has, and its even thickness, but also in its granular contents which I have already shewn, are largely composed of exceedingly rounded grains of quartz and other minerals, often having an extremely high polish. In addition we have, as is usual, a great number of water-worn shell fragments distributed through this seam, and also through the Boulder Clay. It appears to my unsophisticated judgment that there is, with so many evidences present of marine and aqueous agencies, no necessity to go further afield for an explanation. At the same time I have no doubt that believers in the universality of land-ice as a geological agent will find no difficulty in

squaring all these phenomena with their own views. There seems to be in some things a geological faith that nothing in the way of evidence can shake. If marine exuviæ, and water-worn grains are present, land ice is brought across a sea-bottom to account for it. If one points to the evidence of aqueous deposition in the beds, which it is presumed, have been so pushed up, melting of the ice is called in as the agent. If attention is called to the entire absence of all signs of crumpling and contortion, one is told that glaciers frequently move over soft beds without disturbing them. I confess I am unable to see the reasonableness of this sort of way of settling everything in favour of one's own pet geological agent. Depend upon it the obvious and direct explanation, when there is one, is in things geological, as in others, most likely to be the nearest to the truth. When those ardent glacialists, who say that the Lancashire and Cheshire Low-level Boulder Clay and Sands were pushed up from the bottom of the Irish Sea, and laid in a regular semi-stratified sheet on the land, can point to a sheet of ice doing the same thing at the present day, leaving within its ground-moraine erratics of tons weight, and boulders of all sizes, from the pebble upwards, with no signs of disturbance of the deposits in which they are embedded, even when these are stratified and laminated, then their theories may possess more force than they do now. As a geologist of the Lyellian stamp, it appears to me that the dragging in of an agent of which we know almost nothing to explain that which appears simple and obvious is not true philosophy.

Much of the glacial speculation of the present day, to my mind, is neither more nor less than the act of taking certain things for granted, and then deducing enormous consequences therefrom.

EXAMINATION OF GLACIAL WATERS AND DEPOSITS FROM THE RHONE VALLEY, AND NEAR GRINDELWALD, AND OF GLACIAL WATERS FROM NEAR CHAMOUNIX.

By P. Holland, F.C.S., F.I.C., and E. Dickson, F.G.S.

In the paper communicated in the earlier part of the present session, a brief description was given of the ancient glacial deposits found in the Rhone Valley, and a more detailed description of the two glaciers, with the accompanying moraines and streams which descend far down into the Grindelwald Valley.

Both in this paper, and in that communicated by Mr. Cumming to this Society last session, attention was called to a fact which has attracted the notice of several observers, viz.: That both under the Glaciers, and in their vicinity, there was an absence of what, speaking either chemically or geologically, could be called "a clay." It occurred to us that it might prove of interest and of value, if an examination were made of the water of the streams proceeding from the tongues of the glaciers, and of the sediments brought down in them and by them, and see what explanation, if any, could be given to account for the absence of clay.

In addition, however, to the sediment brought down by the streams, there was other material which we considered it would be important to examine, namely, that fine material (the result of the "kneading" process carried on in the body of the glacier) which, acting as a cement, enables a moraine, left by the retreating glacier, to maintain itself at so steep an angle as that of 40°. Such a moraine was described by Mr. Cumming as having been left by the Breslau Glacier, and a moraine with a similar slope was described in the paper before referred to, as having been left by the Upper Grindelwald Glacier.

At the outset we may perhaps be allowed to say this, that although we may not have been able to form any definite conclusions, yet that the facts we have been enabled to ascertain and put together may be of use to future observers, and we have examined the question sufficiently to satisfy ourselves that the problem of the origin and developement of clays, especially of glacial clays, is one of great interest, although of very considerable difficulty.

It will be the more convenient plan to consider, in the first place, the general character and composition of the water of the streams that invarably flow from beneath the tongues of glaciers.

All glacier streams have a great similarity in appearance. The waters of all have a greyish-blue look as they flow, due probably to the fine bluish-grey sediment with which they are all to a more or less extent charged. In some cases, for example in the water flowing from the Grindelwald Lower Glacier, this colouring may also be in some measure due to carbonate of lime, derived from the limestone rock over which the ice and the water travel. There is an immense difference in the amount of suspended matter held by various streams, and in the same stream at different periods of the year. In the winter and spring, before the melting of the ice and snow commences, the streams are comparatively clear and of small volume, but in the summer and autumn, not only is the volume increased, but the amount of sediment held in suspension is enormously increased in proportion.

Another interesting and important fact is that the matter *dissolved* in the water (that is the saline matter) is in inverse proportion to the volume of the stream. These facts will be more evident if we compare observations made on waters collected at different times.

In August 1888, water was collected from the Arveiron, near its source beneath the Glacier des Bois; in March 1889, from the Rhone, about a quarter of a mile above its entrance into the Lake of Geneva; in the same month from the stream issuing from beneath the Lower Grindelwald Glacier; in July, 1890, from the stream flowing from the Mer de Glace, and (for the second time) from the Arveiron. On the latter occasion (July, 1890) two specimens were collected at different points of the respective streams.

The following Table gives the results obtained on examination of the various waters:—

Date.	Stream.	Insoluble suspended matter, grains per Imperial gallon.	Soluble Saline matter, grains per Imperial gallon.
August, 1888	Arveiron	14·2	4·18
March, 1890	Rhone	6·62	23·73
March, 1890	Lower Lutschine	6·58	16·24
July, 1890	Arveiron (1) fine matter	17·97	1·54
	(2) ,,	16·38	
July, 1890	Mer de Glace (1) fine matter	25·20	1·05
	(2) ,, ,,	24·80	

Thus the Rhone, which is generally given as an example of a turbid glacial stream, in March contained only quarter of the suspended matter, but twenty-three times as much soluble matter as did another glacial stream in July. The water, it should be stated, was collected in such a way as to insure the collecting bottle (a wide mouthed one) being rapidly filled with the incoming water. The difference in composition both of the soluble and of the suspended matter goes to show that the waters of the Arveiron and of the stream from the Mer de Glace, were almost entirely the products of rapidly melting ice, in which no saline matter is present.

It would appear that Dolfus, who examined the water of the Aär many years ago at some metres distant

from the glacier of that name, found the suspended matter at the surface of the river to be 14·2 parts per 100,000, or 9·94 grains per gallon. It has been estimated, and the observation is interesting to note here, that from the end of the Aär glacier there escapes every day in August 440,000,000 gallons of water containing 280 tons of sand.

This very considerable difference in composition of waters at different periods of the year has, moreover, an important bearing on the question as to the source or origin of the water that flows from the glacier in the winter months.

With regard to the suspended matter itself, in the case of that contained in the waters of the Rhone and of the Lutschine the matter was exceedingly fine, indeed so fine that when shaken it took several weeks to settle. Some of the matter was flocculent, but the greater portion consisted of angular fragments of very fine sand. The specimens of water collected in July, 1890, from the Arveiron and the stream from the Mer de Glace contained (1) coarse sand that settled rapidly, (2) sand of a finer description, and in addition (3) matter remaining in suspension for several days after collection. For this reason it has been thought desirable to give the figures for the coarse sand separately, and to include with the finer sand the matter that takes so long to settle. At each source the collections were made within a few minutes of each other.

The water from the Arveiron, July, 1890:

	No. 1 Collection, grains per gall.		No. 2 Collection, grains per gall.
Coarse Sand	13.64	..	14.91
Very fine Sand and suspended matter	17-97	..	16.38
Total	31.61		31.29

The stream issuing from the tunnel of ice at the extremity of Mer de Glace, July, 1890:

	No. 1 Collection, grains per gall.		No. 2 Collection, grains per gall.
Coarse Sand........	22.05	..	21.75
Very fine Sand and suspended matter	25.20	..	24.80
Total..............	47.25		46.55

It should be mentioned that this stream was of greater volume than the Arveiron, and the bed appeared to have more inclination; a further noteworthy fact in the case of the two specimens of water from this stream is, that not only was a larger total contents of coarse water-borne material observable, but a larger total also of fine sand and suspended matter generally than was found in the specimens from the Arveiron. The fact would appear to indicate that the rock-mass underlying the Mer de Glace is of softer material than is the bed of the Glacier d'Argentiere, or the difference may be accounted for by the difference in amount and character of debris brought on and by the respective glaciers.

To satisfactorily answer the question as to the reason for the absence of true clays in glacial districts, it was necessary that a complete analysis of the glacial water be made, and for this purpose four litres (nearly one gallon) were collected at Chamounix, and sent to England.

Of the 23·73 grains per gallon of saline or dissolved matter found in the Rhone water, 13·10 grains consisted of sulphate of lime, the remainder being chiefly carbonates of lime and magnesia. The chloride of sodium did not exceed 0·32 grains per gallon. In like manner the 16·24 grains per gallon, the amount present in the water from the Lower Grindelwald Glacier, was found to consist chiefly of sulphate and carbonate of lime, with but little chloride of sodium. Again the

1·54 grains per gallon found in the water of the Arveiron collected in July, 1890, consisted chiefly of sulphate of lime along with carbonates of lime and magnesia, and a little chloride of sodium. The sulphate of lime weighed 0·81 grains of the total, and the chloride of sodium 0·28 = 1·09.

The total saline contents of the water of the Mer-de-glace was 1·05 grains per gallon, and of this 0·62 was sulphate of lime and 0·35 chloride of sodium, making 0·97; the difference being mainly carbonate of lime and magnesia. Whilst considering the saline contents of river or spring water, one must not omit to include the alumina, ferric oxide, ferrous oxide, manganous oxide and silicic acid, all of them derived from the strata over or through which the water may have passed, and all of them constituents of most forms of clay, where clay exists. Silicic acid, a frequent constituent of the soluble solids, amounted to 0·32 grains per gallon in a well of water from Ormskirk, examined by us in 1868. Mr. Wanklyn in his "Water Analysis," mentions 0·5 grains as not uncommon. In the article "Water" (Watt's Dictionary of Chemistry) occurs a table of analysis of a large number of waters from which the following figures are taken, as being of interest in this connection.

The figures given in the Table are in parts per million. They are here stated in grains per gallon.

Per gallon	$Al_2O_3 + Fe_2O_3$ + MnO.	SiO_2
Lake of Geneva	—	0·070
Rhone, near Geneva	0 263	1·666
River Aär, near Berne	—	0·189
" Arve	—	0·140
" Lutschine	0·070	0·245
Farnham, Surrey	0·896	0·994
Well at Hanwell	0.322	0·182
St. Winifred's, Holywell	—	2·737

The silica found in water (when not as sand) is for the most part combined with earthy or with alkaline

bases, though some may be free, inasmuch as hydrated silicic acid is soluble in water *per se*.

It may be asked how comes the hydrated silicic acid in the water, since silica in its familiar form of sand is insoluble in water. The explanation is that when silicates, such as the silicates of aluminium or potassium (and these constitute the basis of felspar and many other rock forming minerals) are decomposed in the presence of water, a portion of the silicic acid set free is retained in the soluble state in the decomposing fluid. For our purpose the decomposing fluid may be water in conjunction with carbonic acid or some other more efficient agent.

To return to the glacial waters. With regard to the matters they carry in suspension, we will merely repeat what was stated in the paper read in the earlier part of this session, that the grains are finer, the further they are collected from the glacier. By far the greater part consist of grains of quartz, the rest of many different kinds of rocks. Examined microscopically, the larger grains are subangular, a small proportion only being quite rounded, but the minute grains of quartz are almost without exception very angular.

A chemical examination of the fine sandy material from the edge of the Arveiron, gave as a result—

80·82 of Silica.
10·26 Al_2O_3.
1·34 Ferric Oxide.*

Although the result showed 10·26 of alumina, it must be understood that this was not present as a product of decomposed felspar, which goes to form clay. This is is a point which will be dealt with more fully later on in this paper.

*Proceedings of the Liverpool Geol. Soc., 1890.

The nearest approach to a "mud or a clay" was found in the sediment deposited in the delta of the Rhone formed where that river enters the Lake of Geneva. The delta occupies an area of about 34 square miles. The depth is unknown. When wet the material feels and looks rather like a clay or mud, but when dry it has a light greyish-blue colour, and is found to consist of a very fine micaceous sand. It has no plasticity, and does not soil the fingers. A portion of this was taken and dried at 212°. A weighed amount was next washed by elutriation, so as to separate any matter of the nature of a clay. Both sand and clay were then collected, re-dried, and weighed. The approximate composition determined in this way, was found to be

Fine Sand....	94·56
Clay	5·44
	100 00

The sandy deposit effervesced when treated with dilute acid, as did also the clay.

An analysis of the sandy material dried at 212° F., gave the following result:

Total, SiO_2	61·97
Al_2O_3	11.82
Fe_2O_3	5·52
MnO	·32
TiO_2	·21
CaO	8·12
MgO	2·19
CO_2	3·70
K_2O	2·17
Na_2O	2·44
Water and matter not determined....	1·54
	100·00

This shows the sandy material to contain 20 per cent. *less* silica than the Arveiron deposit, whilst the alumina was about the same in both. The lime and magnesia are present partly as silicates, the carbonic acid found in the analyses being insufficient to satisfy the total of these bases.

An analysis of the separated clay, dried at 212° F. gives the following result:

Total,	SiO_2	49.37
	Al_2O_3	20.64
	Fe_2O_3	6.71
	MnO.	....
	TiO_2	....
	CaO	8.45
	MgO	3.47
	K_2O	....
	Na_2O	....
	CO_2	4.27
Combined water and matter not determined		7.67
		100.00

In this analysis owing to the small amount of material at our disposal we were obliged to content ourselves with the estimation of only five constituents. The figures 4·27 for the carbonic acid are given on the assumption that the proportion of this acid to the CaO and MgO will be the same as in the preceding analysis, wherein the carbonic acid was directly estimated. Although we have called the separated portion "a clay," still it is a question whether it should strictly be termed a clay, which in the chemical sense is a material consisting, in the main, of hydrated silicate of aluminium; inasmuch as the substance, we separated from the delta deposit, contains too large a proportion of silica. Professor Thorpe, in his "Quantitative Analysis," defines clay as a "Hydrated Aluminium Silicate, derived from the decomposition of felspar." The Porcelain clay of the Chinese is almost pure hydrated silicate of aluminium, containing undecomposed felspar and free silica. Thus the fact must not be lost sight of that the formation of clay is not due to the mere molar disintegration of clay-forming rocks such as the granites) and the subsequent kneading of the detritus with water, but that for the production of clay, we must have the chemical action as well, such action consisting in a partial splitting asunder of the

silicic acid and aluminium, and a recombination of both, with a due proportion of water to form what in reality is a new compound, namely, hydrated aluminium silicate, the basis of all true clays.

We will now deal with the fine cementing material alluded to at the commencement of this paper, and which has been regarded as the result of a kneading process carried on in the body of the glacier. When gathered, it was so hard that a chisel was required to obtain a portion, but owing to shaking in travelling the material had resolved itself into small stones, gravel, and a greyish powder. A fair sample of the whole was taken and weighed. It amounted to 128·5 grammes. When sifted through fine wire gauze, it gave 101·0 grammes of stones and gravel, and 27·5 grammes of powder. It was therefore made up in 100 parts of

Stones and gravelly sand......	79·1.
Powder	20·9.
	100·0.

and contained, when examined, 0.21 per cent. of moisture.

The powder effervesced strongly when moistened with dilute acid, thus indicating a considerable amount of carbonates. As one object of the chemical examination was to ascertain the cause of the strongly marked cohesive character of the material, the plan of analysis was that usually adopted for clays.

The following figures were obtained :—

Total matter insoluble in acid consisting of sand, felspar, silicic acid in loose combination, and hydrated silicic acid.	54·76
Aluminium and Iron Oxides .. (ferric oxide, only small)	7·32
Lime	19·10
Magnesia......................	1·13
Carbonic Acid	16·31
Moisture at 212 F...............	0·21
Combined water, with humic matter not determined........	1·17
	100·00

The next analysis shews the probable composition of the grey powder which cannot be regarded as a clay:—

Sand and felspar	48·730
Uncombined Silicic Acid	4·870
Silicate of Alumina $Al_2\ O_3\ 2\ Si\ O_2\ 2\ H_2O$	8·480
Carbonate of Lime	34·107
Carbonate of Magnesia................	2·373
Moisture (loss at 212° F.)	0·210
Combined Water with humic matter not estimated	1·170
	99·940

On reviewing the information the foregoing analyses afford, two explanations of the cementing together of the particles of powder present themselves. We may fairly assume as one explanation the concreting action of the free silicic acid, a mechanical rather than a chemical one. It will be observed that the lime and magnesia exist as carbonates and not as silicates. Had the carbonic acid been insufficient to saturate these two bases completely a partial silicification of what remained of them would, perhaps, account for the cohesive character of the morainic material. A second explanation would be the action of the carbonates themselves, whereby under the influence of moisture, charged with carbonic acid there would be a partial solution of the calcareous matter, as calcic bicarbonate in the upper layers to be later on redeposited as insoluble neutral carbonate in the lower layers of the moraine. In this way the particles of matter composing the moraine would become encrusted and cemented together. It must not, however, be lost sight of that statical pressure alone acting for a long period of time on the mass composing the inferior layers of the moraine will also be a largely contributing factor.

The question may now fairly be asked, if none of these sediments and fine morainic material be a clay, in what respect do they differ from a clay.

The answer to such a question will be, that although the analyses shew the sediments to be potentially clay-forming substances, the chemical changes whereby clay

is produced have not yet taken place. The hydration of the alumino-ferric contents of the clay-yielding rocks will doubtless be one of the "long results of time."

In order to try and throw some light on the formation of clay we have commenced a series of experiments, and hope to bring the results before this Society, along with some analyses already made of the Boulder Clay collected from different parts of the country.

A FURTHER NOTE ON THE DECOMPOSED BOULDER AND UNDERLYING RED SANDSTONE IN THE CHAPEL STREET SECTION, LIVERPOOL.

By T. Mellard Reade, C.E., F.G.S.

Since I read the preceding paper to the Society, I have carefully examined the portions of the boulder and attached sandstone rock which I exhibited to the meeting on the 10th of March. This I had been precluded from doing earlier from want of time and daylight, the specimens having been kept at the office.

The result has been an interesting revelation, confirmatory of the views I have already expressed. To make my explanation plain, I exhibit a coloured drawing, the natural size of the object. The boulder is cemented to the sandstone, but between it and the rock is a thin film of indurated clayey sand which expands to a greater thickness on the opposite side to that shewn by the drawing. Immediately below this is a hard indurated shell of sandstone rudely concentric to the boulder with irregular patches of a similar nature, These small indurated patches are found on the other side

in the mass of the sandstone. In the indurated shell of sandstone, close to the boulder, are to be seen in places with a lens, minute specks of the greenstone. On the opposite side to that shewn in the drawing the shell of indurated sandstone is more irregular and thinner. Below the indurated shell in places are patches of loose clayey sand. On the opposite face genuine Boulder Clay is attached to it, apparently infiltrated into a joint or cavity of the sandstone.

An examination of a fragment of the concentric indurated shell of sandstone under the microscrope, shews that there has been a deposit of silica in the interstices of the grains, giving it the appearance of a pinkish arkose, and making the rock nearly solid.

The Boulder Clay in the second specimen from the same boulder which I exhibited is also indurated immediately in contact with the boulder, forming a thin attached shell. These interesting facts show clearly that the boulder was not forced into the solid rock by pressure, but that the now solid and very hard sandstone shell was originally sand from the adjacent rock in which the boulder lay partly embedded, and that it has been hardened and attached to it by the silica liberated in the actual process of decomposition. The decomposition of felspar yields the silica, part of which has been redeposited in the sand, and some in the irregular patches. The whole composition of the immediately underlying rock shows that it has been in a rubbly state, fragments of sandstone and sand therefrom being infiltrated in places with Boulder Clay. It thus appeared soft to me in breaking out the piece, and has hardened by drying.

Liverpool Geological Society.

REPORTS OF EXCURSIONS.

EASTER EXCURSION.

A small party of the Society had a very pleasant six days' excursion, commencing on the 3rd of April, 1890, to Leicester and neighbourhood, under the guidance of one of the members, Mr. Linnæus Cumming of Rugby. On reaching Atherstone they explored some of the principal quarries between Atherstone and Nuneaton. The Hartshill quartzite and associated beds are, though formerly considered to be Carboniferous, now known to be Lower Silurian, thanks to the labors of Professor Lapworth and others. Taking the train from Nuneaton to Leicester the party were joined by Mr. John D. Paul, F.G.S. and Mr. Montagu Browne, F.G.S., F.Z.S. Under the guidance of the latter gentleman, the Brick Pit at Wigston was thoroughly explored. Here is to be seen one of the finest sections in the country, showing the succession from the New Red Marl of the Trias, through the Rhætic to the Lias. Mr. Browne, who has worked the various zones of the Rhætic, pointed out the *Avicula Contorta* bed ard the passage beds between the Rhætics and the Lias. The third day was devoted to the Lias of the Barrow-on-Soar, where Mr. Montagu Browne has discovered numerous fish remains, one of them being new to science. The members collected a variety of characteristic fossils. In the railway cutting Mr. Browne, by a little digging, proved to the satisfaction of the members the position of the *Avicula Contorta* bed of the Rhætics, and showed that the succession of zones at Barrow-on-Soar is the same as at Wigston. On the fourth day Mr. Paul led the party through Leicester to Bradgate Park in Charnwood Forest, pointing out many topographical and archæologica features on the route. The rocks of Charnwood Forest at the south end of the anticlinal at Holgate Hill were examined, and the bedding and cleavage of the strata noted, as well as the igneous intrusions amongst slates at the Stable Quarry, Bradgate Park. The slaty

agglomerates east of the tower called "Old John" were examined, and specimens taken. Bradgate House, of which only some of the walls remain as evidence of the excellence of the brickwork of the fifteenth and sixteenth centuries, was well examined. Historically the building is interesting as having been the scene of Roger Ascham's tuition of Lady Jane Grey. The fifth day the party had to make shift without local guidance, and limited the time to an examination of the celebrated Mount Sorrel Granite (Syenite) quarries. Some very interesting facts were noted here, and good examples of epidote were taken, showing how it had arisen from the decomposition of the constituents of the Syenite. A pleasant walk from Mount Sorrel to Swithland slate quarries, and a drive home, completed the day. The sixth and last day was spent at Rugby, where Mr. Cumming showed the party over the Rugby School, and afterwards the Rugby Cement Works, where the interesting process of the manufacture of Portland cement was observed. While in Leicester the Museum, of which Mr. Browne is curator, was specially lighted up in the evening, and the contents explained to the party. The excellent and artistic arrangement of the birds, and the naturalistic modelling of the backgrounds and surroundings, all the work of Mr. Browne, excited much admiration.

T. MELLARD READE.

REPORT ON EXCURSION TO SHIP CANAL WORKS AT WARBURTON, AND TO SLADE LANE, FALLOWFIELD.

In the autumn of 1889 the Society visited the Warburton Cutting; but as a dense fog prevailed, no real work could be done. On May 17th, 1890, a second excursion was arranged, and the elements were more favourable.

Entering the works at the Hollins Green end, a fine section of the Keuper Marls is exposed. The numerous thin white bands occurring in these beds render the dip very apparent It is about 8°. The rock is of a soft nature, and readily splits into slaty pieces. Salt pseudomorphs of great size and rare beauty are very abundant, and sun-cracks and ripple-marks are also common. A few problematical markings, considered to be worm tracks, were discovered; but no foot-prints have as yet been met with. Some structureless carbonaceous matter has

been found in these beds by Mr. P. F. Kendall, F.G.S., and he regards it as the remains of plants. The Keuper Marls are continued on the other side of the bridge, and here is exposed a very pretty but complicated fault. It is seen on the face of the cutting on both sides. The throw is probably not very great. A little further on is a large fault having a throw of at least 500 feet, which brings the Upper Mottled Sandstone against the Keuper Marls. It was not exposed at the time of our visit. Between the two faults the rock shows evidence of great disturbance, and there are numerous irregular vertical cracks, for the most part filled in with gypsum.

The Triassic rocks are in places capped by Boulder Clay or Glacial Gravel containing boulders of local origin as well as erratics of Loch Doon, Eskdale and Criffel Granites, Buttermere Granophyre (very common), and many of the well-known types of volcanic rocks from the Borrowdale Series.

Above the Boulder Clay again we find river deposits consisting of silt and peaty beds. Numerous tree trunks—mainly oak and poplar—occur in these, along with leaves and nuts, and at one place there was quite a large patch consisting of hazel nuts, many of them evidently having been gnawed by squirrels.

After examining the Warburton cutting the party, accompanied by Mr. P. F. Kendall, F.G.S., and Mr. J. W. Gray, F.G.S., visited a new section exposed in the cutting of a new railway near Slade Lane, Fallowfield. The length of the section was about half a mile, and its main interest lay in the fact that a complete transition from the Carboniferous to the Triassic rocks was shown.

At the E. end the Carboniferous sandstones and shales are seen containing numerous bands of Ardwick limestone. The dip is from 18° to 20° W. The Permian rocks appear a little W. of the bridge, and lie conformably on the Carboniferous Series.

At the base we have the Collyhurst sandstones, showing a thickness of about 510 feet. A grit band 7 feet thick succeeds, forming the base of the overlying Permian Marl, which has a thickness of 60 feet, and is faulted against the Lower Bunter.

The slickensided face of the fault was very well exposed at the time of our visit, and a bed of marl in the neighbourhood of the fault was curved so much as to be turned completely over. The marl contains many calcareous fossiliferous concretions.

The section throughout its whole length was overlaid with glacial deposits. These consist of a stiff clay with occasional bands of sand, and containing many scratched stones. Just above the sandstones a bed occurs consisting mainly of angular fragments of the rock beneath.

Boulders are found in this 3 or 4 feet below the clay, and tongues of clay are sometimes thrust into the rubbly mass below.

The pieces forming this band have in every case a position eastwards of the outcrop. The limestones being easily recognised were especially noticeable, and some were moved as much as 30 yards eastwards. This was admitted to be a ground moraine, and was believed to indicate the presence of land ice.

Boulders found *in situ* showed glacial striæ having a bearing of N. 75° W.

J. LOMAS.

MEMBERS
OF THE
LIVERPOOL GEOLOGICAL SOCIETY.

HONORARY MEMBERS.

WILLIAM BRYHAM, Wigan.
CHAS. CALLAWAY, D.Sc., F.G.S., Wellington, Salop.
ARCHIBALD GEIKIE, D.Sc., F.R.S., London.
HENRY HICKS, F.G.S., M.R.C.S.E., London.
JOHN W JUDD, F.R.S., F.G.S., London.
*DANIEL MACINTOSH, F.G.S., 32, Glover Street, Birkenhead.
WILLIAM PENGELLY, F.R.S., F.G.S., Torquay.
SIR A. C. RAMSAY, F.R.S., F.G.S., London.

FOREIGN CORRESPONDING MEMBERS.

M. A. DAUBRÉE, Museum of Natural History, Paris.
DR. A. HEIM, University of Zurich.
MAJOR-GEN. N. VON KOKSCHAROW, Inst. of Mines, St. Petersburg.
PROF. J. VILANOVA-Y-PIERA, University of Madrid.
DR. A. F. RENARD, Museum of Natural History, Brussels.
BARON F. VON RICHTHOFEN, Berlin.
PROF. J. J. STEVENSON, University of New York.

MEMBERS.

*ARCHER, F., B.A., 14, Cook Street.
*†BEASLEY, H. C., (*Hon. Secretary*), Prince Alfred Road, Wavertree.
*BROWN, J. CAMPBELL, Prof., D.Sc., F.C.S., 27, Abercromby Square.
CHALMERS, E. R., 54, Park Road South, Birkenhead.
CLAGUE, D., F.G.S., 81, Lime Grove.
*CUMMING, L., M.A., 14, Bilton Road, Rugby.
DAVIES, D., 55, Berkley Street.
DAVIS, T. H., F.I.C., 14, Imperial Chambers, Dale Street.
*DICKSON, E., F.G.S., 30, Eastbourne Road West, Birkdale.
*ESKRIGG, R. A., F.G.S., The Woodlands, New Brighton.
18, Hackins Hey.
FITZPATRICK, M., 62, Seel Street.
*FITZPATRICK, J. J., 62, Seel Street.
FOSTER, E., 41, Arundel Avenue, Sefton Park.
*GEORGE, I. E., 16 Wynnstay Street.
GOFFEY, T. Nicholas Road, Blundellsands.
GOODALL, W,, 43, Walmer Road, Birkdale.
GORDON, A., 168, Islington.
HANCE, E. M., LL.B. (*Hon. Treasurer*), Municipal Offices, Dale Street.
*HERDMAN, W. A. Prof., D.Sc., F.R.S.E., University College.

*HIGGINS, Rev. H. H., M.A., 29, Falkner Square.
HILL, H. ASHTON, C.E., Wallasey Gaz and Water Works, Liscard.
*HEWITT, W., B.Sc., 16, Clarence Road, Birkenhead.
*HOLLAND, P., F.C.S., 26, Talbot Street, Southport.
*JEFFS, O. W., 12, Queen's Road, Rock Ferry.
KELLY, J. DUNBAR, 4, Sweeting Street.
KENNARD, J., F.R.G.S. 38, Elm Grove, Birkenhead.
KEYTE, T. S., C.E., 9, Chatham Place.
KNIGHT, A. H., F.C.S., 22, Radnor Place, Claughton.
LINDSAY, R. C., B.Sc., 112, Anfield Road.
*LOMAS, J., Amery Grove, Woodchurch Lane, Birkenhead.
LUTSCHAUNIG, A., 33, St. James' Road, Liverpool.
MOORE, C. C., 125, Chester Road, Hartford, Northwich.
*MARRAT, F. P., 13, Nursery Lane, Broad Green.
MILES, C. E., 57, Willow Bank Road, Tranmere.
MILES, W. H., 9, The Woodlands, Birkenhead.
*MOORE, T. J., C.M.Z.S.L., 14 Gardner Road, West Derby,
Liverpool Museum.
MORTIMER, Captain, Liverpool.
*†MORTON, G. H., F.G.S., F.R.G.S.I., 209, Edge Lane.
PATERSON, J., C.E., F.G.S., Palmyra Street, Warrington.
PALMER, S. J., M.B., M.R.C.S., Netherfield Hospital.
PLANT, DR. H. W., 57, Upper Warwick Street.
*POTTER, C., 101, Miles Street.
*†READE, T. M. C.E., F.G.S., Park Corner, Blundellsands.
Canning Chambers, South Castle Street.
*†RICKETTS, C., M.D., F.G.S., 19, Hamilton Square, Birkenhead.
RICHARDSON, W. A., C.E., Valley Lodge, Borough Road, Birkenhead.
ROBINSON, J. J., 36, York Road, Birkdale.
ROCK, W. H. 75, Botanic Road.
*SEMMONS W., 29, Great St. Helens, London.
SHONE, W. F.G.S., Upton Park, Chester.
SLATER, S., 16, Hayman's Green, West Derby.
*TATE, A. NORMAN, F.I.C., F.C.S., F.G.S., 9, Hackins Hey.
*TIMMINS, A., C.E., Argyll Villa, Runcorn.
TUNSTALL, J., 45, Vine Street.
TWEMLOW, J., 1, May Street.
*WARD, T., Brookfield House, Northwich.

ASSOCIATES.

MORTON, Miss S. E., 209, Edge Lane.
READE, Mrs., Park Corner, Blundellsands.

---

* Have read Papers before the Society.
† Contribute annually to the Printing Fund.

CONTENTS.

PROCEEDINGS

OF THE

Liverpool Geological Society.

SESSION THE THIRTY-THIRD,

1891-92.

Edited by H. C. BEASLEY.

(The Authors, having revised their own Papers, are alone responsible for the facts and opinions expressed in them).

PART 4. VOL. VI.

LIVERPOOL:
C. TINLING AND CO., PRINTERS, VICTORIA STREET.
1892.

PROCEEDINGS

OF THE

Liverpool Geological Society.

SESSION THE THIRTY-THIRD,

1891-92.

Edited by H. C. BEASLEY.

(The Authors, having revised their own Papers, are alone responsible for the facts and opinions expressed in them.)

PART 4. VOL. VI.

LIVERPOOL:
C. TINLING AND CO., PRINTERS, VICTORIA STREET.

1892.

OFFICERS 1891-92.

President:

WM. HEWITT, B.Sc.

Ex-President:

C. RICKETTS, M.D., F.G.S.

Vice-President:

E. DICKSON, F.G.S.

Hon. Treasurer:

E. M. HANCE, LL.B.

Hon. Librarian:

J. J. FITZPATRICK.

Hon. Secretary:

H. C. BEASLEY.

Council:

H. ASHTON HILL, C.E.
J. LOMAS, Assoc. R.C.S.
F. R. CHALMERS.
G. H. MORTON, F.G.S.
T. MELLARD READE, C.E., F.G.S.

LIST OF SOCIETIES, ETC., TO WHICH THE PROCEEDINGS OF THE LIVERPOOL GEOLOGICAL SOCIETY ARE SENT.

(Publications have been received in exchange during the Session from those marked).*

*Academy of Natural Sciences, Philadelphia.
Advocates' Library, Edinburgh.
*Australian Museum, Sydney.
*Belfast Naturalists' Field Club.
*Birkenhead Free Public Library.
* ,, Literary and Scientific Society.
Birmingham Philosophical Society.
*Bootle Free Public Library.
British Museum.
British Museum (Natural History) Geological Department.
*British Association for the Advancement of Science.
Bristol Naturalists' Society.
Bodleian Library, Oxford.
*Boston Society of Natural History, U.S.
*Chester Society of Natural Science.
*Colorado Scientific Society.
Dudley and Midland Geological and Scientific Society.
*Essex Naturalists' Field Club.
Editor of "Geological Record."
,, "Nature."
,, "Geological Magazine."
Editor of "Science Gossip."
Ertborn, Le Baron O. Van, Anvers, Belgique.
Geological Society of Edinburgh.
*Geological Society of Glasgow.
*Geological Society of London.
*Geological Society of Manchester.
Geological Society of Norwich.
*Geological Society of Australasia, Melbourne.
*Geological Survey of the United States.
Geological Survey of India.
*Geological Survey of Canada.
*Geological Survey of Missouri.
Geological Survey of Sydney, N.S.W.
*Geologists' Association, London.
*Glasgow Philosophical Society.
Hungarian Karpathian Society, Locse.
Imperial Academy of Naturalists, Halle, Prussia.

*Kansas Academy of Sciences, Topeka.
*Leeds Philosophical and Literary Society.
*Leeds Geological Association.
Liverpool Athenæum.
,, Chemists' Association.
* ,, Free Public Library.
* ,, Geological Association.
,, Literary and Philosophical Society.
,, Lyceum Library.
,, Philomathic Society.
* ,, Engineering Society.
,, Astronomical Society.
,, Science Students' Association.
L'Universite Royal de Norvége, Christiana.
*Manchester Association of Engineers.
*Manchester Literary and Philosophical Society.
*Manchester Geographical Society.
Minnesota Academy of Natural Science, Minneapolis, U.S.
Musée Royal d'Histoire Naturelle de Belgique.
*Museu Nacional, Rio de Janeiro.
Museum of Practical Geology, Jermyn Street, London.
*North of England Institute of Mining and Mechanical Engineers.
New York Academy of Sciences.
*Owens College, Manchester.
Patent Office Library, 25, Southampton Building, Chancery Lane, London, W.C.
*Rassegna delle Scienze Geologiche in Italia.
*Rochester N.Y. Academy of Science.
*Royal Dublin Society.
Royal Geological Society of Ireland, Dublin.
Royal Society, London.
Smithsonian Institution, Washington, U.S.
*Société Geologique de Belgique, Liege.
Société Geologique du Nord, Lille.
*Société Impériale des Naturalistes de Moscow.
*Société Royale Malacologique de Belgique.
*Sociedade de Geografia de Lisbon.
*Toscana Societa di Scienza Naturali.
*University Library, Cambridge.
University College, Bangor.
,, ,, Liverpool.
*Warwickshire Natural History and Archæological Society.
Watford Natural History Society.
*Wagner Free Institute of Science, Philadelphia.
*Woodwardian Museum, Cambridge.
Yorkshire Geological and Polytechnic Society.

PROCEEDINGS

OF THE

LIVERPOOL GEOLOGICAL SOCIETY.

SESSION THIRTY-THIRD.

OCTOBER 13th, 1891.

The President, W. HEWITT, B.Sc., in the Chair.

The Hon. Treasurer submitted his Statement of Accounts.

The Officers and Council for the ensuing year were elected.

NOVEMBER 10th, 1891.

The President, W. HEWITT, B.Sc., in the Chair.

Mr. G. J. Hill was elected an Ordinary Member.

The following Paper was read:—

ON THE ROUNDING OF SAND GRAINS OF THE TRIAS AS BEARING ON THE DIVISIONS OF THE BUNTER.

By T. Mellard Reade, C.E., F.G.S.

DECEMBER 8th, 1891.

The President, W. HEWITT, B.Sc., in the Chair.

The following Paper was read:—

MUD AVALANCHES.

By E. Dickson, F.G.S.,

And a NOTE upon it, by L. Cumming, M.A.

The Report of the Committee appointed by the Society, 12th February, 1889, to report on Boulders in the neighbourhood of Liverpool was presented, including:

REPORT ON THE BOULDERS ON THE SHORE OF THE MERSEY FROM THE DINGLE TO HALE POINT.

By J. Lomas, Assoc. R.C.S.

REPORT ON THE BOULDERS AT BEBINGTON.

By O. W. Jeffs.

JANUARY 12th, 1892.

The President, W. HEWITT, B.Sc., in the Chair.

Mr. O. W. Jeffs presented his Report as Delegate to the British Association Meeting at Cardiff, 1891.

The following Paper was read:—

ON THE COAST SECTION FROM EXMOUTH TO SIDMOUTH, AND PARTICULARLY ON THE BUDLEIGH SALTERTON PEBBLE-BED.

FEBRUARY 9th, 1892.

The President, W. HEWITT, B.Sc., in the Chair.

The following Papers were read:—

SOME EAST AND WEST FAULTS AT CALDY GRANGE.

By J. Lomas and H. C. Beasley.

POT-HOLES ON THE SHORE NEAR DINGLE POINT.

By J. Lomas, Assoc. R.C.S.

NOTES ON SOME SECTIONS NEAR TUNBRIDGE WELLS.

By F. R. Chalmers.

MARCH 8th, 1892.

The President, W. HEWITT, B.Sc., in the Chair.

The following Papers were read:—

THE TRIAS OF CANNOCK CHASE.

By T. Mellard Reade, C.E., F.G.S.

THE BUNTER CONGLOMERATE NEAR CHEADLE, STAFFORDSHIRE.

By H. C. Beasley.

APRIL 12th, 1892.

The Vice-President, E. DICKSON, F.G.S., in the Chair.

The following Papers were read:—

SOME FAULTS EXPOSED IN A QUARRY NEAR THINGWALL MILL, CHESHIRE.

By J. Lomas, Assoc. N.S.S.

REPORT ON THE SOCIETY'S EXCURSION TO SETTLE, WHITSUNTIDE, 1891.

By C. Ricketts, M.D., F.G.S.

FURTHER NOTES ON THE DEEPDALE BONE CAVE, NEAR BUXTON.

By J. J. Fitzpatrick.

Field Meetings were held at—

Neston, 19th September, 1891.

Borough Road Waterworks, Birkenhead, 9th April, 1892.

LIVERPOOL GEOLOGICAL SOCIETY,

Dr. *In account with* E. M. Hance, *Hon. Treasurer, Session* 1890-91. **Cr.**

	£	s.	d.		£	s.	d.
To Hon. Librarian's Expenses, 1889-90	0	8	0	By Balance brought forward	11	1	1
,, Hon. Secretary's ,, 1890-91	3	1	6	,, Subscriptions for current Session...	23	12	6
,, ,, ,, *re* Excursions......	0	3	9	,, ,, Arrears.................	1	11	6
,, E. Doling, Sessions 1889-90-91 ...	13	2	4	,, ,, in Advance............	0	10	6
,, Tinling & Co.—Printing on a/c ...	14	0	0	,, Special Donations......................	1	0	0
,, Rent to 4th October, 1891...........	5	0	0	,, Sale of Proceedings	0	10	0
,, Balance in hand........................	2	10	0				
	£38	5	7		£38	5	7

Audited and found correct,

13*th October*, 1891. (Signed) J. Lomas.

W. H. Miles.

PRESIDENT'S ADDRESS.

THE EARTH IN ITS COSMICAL RELATIONS.

By W. Hewitt, B.Sc., Assoc. R.S.M.

The science of Geology presents itself under different aspects to different classes of minds. To some, it would appear to be almost confined to the record of facts as to the nature and present arrangement of the materials of which the accessible portions of the earth's crust are composed; and such geologists consider as outside the scope of the science any enquiry as to the more remote sources and antecedent conditions of those materials, as also the condition of those parts of the earth which are not open to direct investigation. To others, however, the mere observation and record of the facts has little interest and value, apart from the inferences and conclusions which may be drawn therefrom as to the past history of the earth; and they are consequently always seeking for theories, by means of which to connect and interpret their facts and to suggest further lines of observation and enquiry. And to many minds among this latter class the speculations of the geologist are not of necessity confined within the limits of the accessible portions of the earth's crust, or the period of time which has elapsed since the formation of the earliest sedimentary rocks. They are prepared to receive and to consider any evidence, from any source, as to conditions now obtaining in the deeper parts of the earth, or as to that period of its history which preceded the era of the first sedimentary deposits. They will even entertain any well-founded theory, based upon observation and experiment, as to the probable source of the materials which are now aggregated together to form the mass we know as our globe.

Sir Archibald Geikie, in his well-known "Text Book of Geology" (p. 7), says that "Whatever extends our knowledge of the former conditions of our globe may be legitimately claimed as part of the domain of geological enquiry;" and Professor Prestwich, in his "Geology" (vol. i., p. 2), defining the range of the subject as now understood, says "It commences with questions of cosmogony, and ends with the *status quo* of the present period."

I think, therefore, that I shall be justified in asking your attention, as geologists, to some of the cosmical relations of the earth, viewed in the light of some recent theories and researches; which, when further developed, may possibly furnish us with valuable information concerning certain very obscure chapters in the earlier stages of the earth's history.

The relation of the matter constituting our globe to that of which the other bodies of the Solar System, or the still more remote bodies of the Universe, are formed, was until comparatively recently a mere matter of conjecture; except in so far as the information obtained by the examination of meteorites (assuming them to be of extra-terrestrial origin) might be regarded as fairly representative. When, however, the spectroscope gave to the astronomer the means of determining, by examination of the emitted light, the chemical composition of the luminous substance, the important discovery was made that all the self-luminous bodies of the Universe are composed of matter identical in kind with that constituting our earth, so far at least as its elementary composition is concerned. Hydrogen, iron, nickel, sodium, potassium, magnesium, calcium, barium, copper, manganese, aluminium, and other elements have been shown to exist in the atmosphere of our sun, while the

presence of many of these elements has been recognised in one or other of the so-called fixed stars. It is, however, a remarkable fact that no satisfactory evidence exists of the presence in the sun of either oxygen or silicon, the two elements which together are believed to constitute not less than seventy-five per cent. of the earth's crust.

In view of this identity of matter among the numerous and apparently independent bodies forming the Universe as we know it, it is only natural to ask whether any reason can be suggested for the relation; whether there is any ground for thinking that these bodies had in any way a common origin, and whether they may possibly have been formed by segregation from a universally distributed primordial substance.

Prof. Norman Lockyer, F.R.S., has recently propounded the theory that all these bodies are formed by a process of growth or evolution, and result from the aggregation of innumerable small masses of matter identical with those which we know as meteorites. His theory is that: "All self-luminous bodies in the celestial spaces are composed either of swarms of meteorites, or of masses of meteoritic vapour produced by heat. The heat is brought about by condensation of meteor swarms due to gravity, the vapour being finally condensed into a solid globe." *

Starting from a scattered meteor-swarm, he conceives that the individual meteorites would, by virtue of their mutual gravitation, be brought into repeated collisions one with another, and that the heat generated by such impacts would be sufficient to produce a considerable amount of vapour in the interspaces; further contraction and condensation would by a repetition of the same

* Lockyer, "The Meteoritic Hypothesis," p. 97.

process, bring the whole mass at last to a state of complete volatilisation, with a very high temperature; this body of glowing vapour as it parted with its heat by radiation would condense and ultimately become transformed into a dead non-luminous globe, such as our moon is now believed to be.

Professor Lockyer founds his theory of the meteoritic origin of celestial bodies upon the results of his long-continued researches with the spectroscope, both upon the heavenly bodies, and more recently upon the light emitted by fragments of meteorites and meteoritic dust heated to comparatively low temperatures in a partial vacuum. In his papers communicated to the Royal Society, and in his recent volume on "The Meteoritic Hypothesis of the Origin of Cosmical Systems," he brings forward evidence to show that we have now, in the depths of space, representative bodies in each one of these several stages of growth—meteor swarms, comets, nebulæ, suns, cooling suns, dark planets, and satellites.

This is not the place to discuss the spectroscopic evidence which Professor Lockyer adduces—that belongs to the province of the physical astronomer, and not of the geologist. The theory, even in its main outlines, is by no means universally accepted; but the one fact which does appear to have been established—viz.: the very close relations which exist between the matter of which meteorites are composed, and that of which various classes of bodies belonging to other systems, and apparently in various stages of progress, are made up—together with the *possibility* that our earth has resulted from an aggregation of similar materials, cannot but be interesting and suggestive to geologists. That some extra-terrestrial matter is constantly being added to the earth's mass seems certain; an enquiry into the nature

and amount of such material as is now being thus - sup plied, and as to the possibility of recognising similar material supplied during past ages, is quite within the scope of geological investigation.

The suggestion of the meteoritic origin of at least a great part of the earth's mass is not now made for the first time. The late Mr. R. A. Proctor many years ago wrote as follows: "Under the continual rain of meteoric matter, it may be said that the earth, sun, and planets are growing,"* and he added as an obvious suggestion that the whole growth of the solar system from its primal condition may have been the result of a similar process. Professor Nordenskiold and others, have speculated on the gradual growth of the earth from cosmic materials; and Sir Wm. Thomson, at the first Liverpool Meeting of the British Association in 1854, argued that the immediately antecedent condition of the matter of which the sun and planets were formed was probably solid, and may have been like the meteoric stones which we meet with, and this opinion he apparently still held at the time of his well-known Presidential Address to the same Association in 1871.

The proved connection, if not absolute identity, of comets with meteor swarms—the observation by Mr. Lockyer that certain comets when at a great distance from the sun agreed in spectroscopic characters with nebulæ—the graduated series which can be traced from the nebulæ through various classes of stars—the very general distribution of meteorites throughout the space traversed by the earth in its vast journeys—and the probability that various meteor swarms have been captured from outer space, and permanently attached to our system by the attraction of the sun and the giant

* "Other Worlds than Ours," chapter ix.

outer planets, have led astronomers to regard these small bodies as having a universal distribution. We must in fact, according to Mr. Lockyer, conclude that "Space is a meteoritic plenum, while the forms [of the self-luminous bodies] indicate motions and crossings and interpenetrations of streams or sheets, the brighter portions being due to a greater number of collisions per unit volume." *

There are, however, it should be said, distinguished authorities who hold that the most probable origin of the ordinary meteorites which fall upon the earth is to be found in the earth itself. Sir Robert Ball holds this view, and suggests that they are masses which were ejected in the earlier ages of the earth's history, when the volcanic forces were much more powerful than at the present day. And to meet the natural objection as to the immense resistance which the atmosphere would oppose to a mass projected with the enormous velocity required to carry it to a sufficient distance from the earth, he supposes them to have been thrown out from craters situated at considerable elevations above the sea level.* If such an origin could be proved, the interest which the study of such masses would have for the geologist anxious to learn something of the composition of the deeper portions of the earth, would still be acknowledged.

A very brief resumé of our knowledge of these "pocket planets," as they have been called, will therefore not be out of place. The meteorites which reach the earth's surface vary in size from very minute fragments to masses of several tons in weight. The Cranbourne meteorite, from near Melbourne in Australia,

* Lockyer, Bakerian Lecture. "Nature," vol. xxxvii., p. 586.
Ball, "Study of the Heavens," p. 365.

now in the British Museum, weighs considerably over three tons. According to Professor Young, the number of meteorites which have fallen since 1800, and which have found their way into our cabinets, is about 250. But this gives no idea as to the vast numbers of such bodies which come into our atmosphere; many of those even which reach the earth's surface will of course do so without our knowledge, while the majority are volatilised and dissipated by the intense heat generated by their exceedingly rapid passage through the air, and reach the earth (as will be afterwards described) probably in the form of microscopic dust particles. As Professor Newton, of Yale College, perhaps our greatest authority on meteors, says, "The air acts as a shield to protect the earth from an otherwise intolerable bombardment." This authority estimates that from fifteen to twenty millions of luminous meteors enter the earth's atmosphere daily; and these, be it noted, are derived not from connected meteor swarms, but are apparently isolated and independent masses—"sporadic" meteors. Although amongst them there may be some of large size, the majority are probably very small. Professor Newton, in his address on "Meteorites, Meteors, and Shooting Stars," to the American Association for the Advancement of Science, 1886, says, "The smallest meteors visible to the naked eye may be thought of without serious error as being of the size of gravel stones, allowing, however, not a little latitude to the indefinite word, gravel." Observations of the light emitted by the meteors in certain star showers, led to the conclusion that the majority weighed less than a single grain, and the largest of them did not reach 100 grains.* Professor S. P. Langley speaking of the quantity of dust thus

* Young, "Astronomy," 1889, p. 439.

poured into the atmosphere, says, "It is difficult to state with precision what the amount is, but several lines of evidence lead us to think that it is approximately not greatly less than 100 tons per diem, nor greatly more than 1,000 tons per diem.* Allowing for the supply of 100 tons of this matter per day, Professor Young points out that it would take 1,000,000,000 years to accumulate a layer one inch thick over the earth's surface.† And Professor Newton, in the address before mentioned, speaking of the theories as to large portions of the earth's crust having been made up of matter thus derived, says of meteorites, "Their effect in producing geologic changes by adding to the earth's strata, has without doubt been very much over-estimated. During a million of years, at the present rate of say 15,000,000 of meteors per day, there comes into the air about one shooting star or meteor for each square foot of the earth's surface."*

In the face of these statements the geologist will scarcely expect to find this cosmic material as having, at the present time, any very considerable importance in the formation of new deposits. There is the possibility, however, that the rate may have been greater in former ages, before the space traversed by the earth was so far swept clear of such material, or that it may vary according to the region of space through which the sun with its dependent planets is at any time moving. These, however, are mere speculations, for which no evidence, so far as I know, exists.

The question will naturally at once suggest itself, whether in the geological record we have any traces of

* Royal Society's Report on the Krakatoa Eruption, p. 420.

† Loc. cit., p. 439.

* "Nature," vol. xxxiv., p. 534.

the inclusion of meteoritic masses among the ordinary materials of which the strata are composed. To this question I will return after briefly stating what has been learnt as to the chemical composition and characters of the meteorites which reach the earth in a form suitable for examination.

While an examination of meteorites has revealed the presence of no new elementary body, not less than 26 of our known terrestial elements have been already recognised*—those most commonly occurring being iron, nickel, phosphorus, sulphur, carbon, oxygen, silicon, magnesium, calcium, and aluminium. When we compare this list with a list of the elements which make up the greater part of the earth's crust, we cannot but note a striking resemblance. According to Prestwich, the following seven elements make up nearly 97 per cent. of the material of the crust—oxygen, silicon, aluminium, calcium, magnesium, sodium, and potassium; while sulphur, carbon, and iron are present in notable quantities. It is, however, important to observe that iron is very much more abundant as a constituent of meteorites than as a constituent of the earth's crust, some meteorites being composed almost entirely of metallic iron (forming, according to Professor Young, perhaps 3 or 4 per cent. of those which have been observed to fall), while the stony meteorites contain also a varying but often considerable proportion of that element. The fact that more than half our known terrestrial elements are as yet unrepresented in meteorites—which has been put forward as an objection to the theory that the materials of the earth's crust have been largely derived from this source—is not of very great weight, when we reflect how very small is the total amount of

* Fletcher. "Introduction to Study of Meteorites."

undoubted meteoritic matter which is available for analysis.

According to the list published by the authorities of the British Museum (edition 1888) of the meteorites represented in their collection—which is one of the finest in the world, and only rivalled by that of Vienna—the sum total of the weights given for the several meteorites of all classes is between 5½ and 6 tons; or if we leave out the Cranbourne meteoric iron, only about 2 tons.

Meteorites are usually considered as belonging to three divisions, (1) Siderites, or those consisting almost entirely of iron (alloyed with nickel); (2) Aerolites, or those composed almost entirely of stone; and (3) Aero-siderolites, composed of mixtures in various proportions of metallic and stony matter. As to the relative proportions of the three classes I may say that in the British Museum list, published in 1888, there are entered 260 meteorites of which the date of fall has been recorded; and these are distributed as follows:—7 Siderites, 4 Siderolites, and 249 Aerolites.

Amongst the stony matter referred to are certain mineral substances, identical in composition and general characters with corresponding terrestrial minerals, *e.g.*, Olivine, Enstatite and Bronzite, Augite, Anorthite and Labradorite, Magnetite and Magnetic pyrites. As Prof. Judd has pointed out these minerals are confined to the ultra-basic rocks of high specific gravity. Chloride of sodium, and sulphates of sodium, calcium, and magnesium, have been extracted from some meteorites by means of water; while others contain considerable quantities of occluded gases, chiefly compounds of carbon and oxygen, or carbon and hydrogen.

Silica, our most abundant terrestrial compound, has been found in meteorites, but not in the form of quartz. Free silica has, however, been recognised in the form of asmanite, which appears to be essentially the same as our mineral tridymite.

As might be expected from the very different conditions under which meteorites must have been formed, certain mineral compounds are present in them which are not known to be represented in our rocks, *e.g.*, Troilite, monosulphide of iron; Cliftonite, a cubic form of graphitic carbon; Oldhamite, sulphide of calcium, &c.

The great resemblance between the composition of certain stony meteorites and that of some terrestrial rocks will, however, be better appreciated by the statement of the results of analysis of two representative specimens. The aerolite of Juvenas, Ardeche, of date 1821, was found to be composed of Pyroxene (Augite) 62·65; Felspar (Anorthite) 34·56; with small quantities of Apatite, Titanate of Lime, Chrome iron, Magnetite, and Magnetic pyrites.* This specimen is said to resemble very closely certain basaltic lavas of Iceland, which are largely composed of Augite and Anorthite.

Dr. Flight gives the composition of the meteorite of Tieschitz, in Moldavia, which was seen to fall in 1878, as Olivine 38·79; Bronzite and Enstatite 33·84; Augite 14·01; Magnetic pyrites 4·08; and Nickel-iron 9·28.*

In a meteorite which fell September 4th, 1886, in the government of Penza, in Russia, and which was composed of a mixture of nickeliferous iron and magnesian silicates (chiefly Olivine), among the carbonaceous matter present was a fine powder having the

* Prestwich. "Geology," vol. 2.

* Flight, Geol. Magazine, July, 1882, p. 314.

hardness of the diamond. M. Daubrée has pointed out the very close resemblance between the substance of this meteorite and the matrix of the diamond as it is found in South Africa. And this resemblance he also shows extends to other similar cases.*

It may here be remarked, on the authority of Prof. Newton, that "The most delicate researches have failed to detect any trace of organic life in meteorites." †

As regards the physical characters of meteorites, I would only now call attention to the fact that in many cases they appear to indicate clearly that the masses as we see them are aggregations, which may have been built up by the collision and partial fusion of numerous smaller bodies. Sorby long ago described some of them as having "many of the characters of a brecciated rock, made up of fragments subsequently cemented together and consolidated."* Many show a peculiar chondritic structure, being composed of numerous spherules or chondroi, embedded in a matrix having a similar composition to themselves, and essentially different from any structure met with in terrestrial rocks.

The important part which iron seems to play in the composition of these bodies—assuming those which we have been able to examine to be fairly representative specimens of the class as a whole—would naturally suggest that if the earth has been, even in part, formed by an aggregation of meteoritic matter, the same element should be as conspicuous as a constituent of the earth's mass. This is not the case, however, with the surface rocks, which alone the chemist is able to examine; but several considerations render it exceed-

* Comptes Rendu. Jan., 1890.

† "Nature," vol. xxxiv., p. 533.

* Sorby. "Nature," vol. xv., p. 495.

ingly probable that iron forms a very large proportion of the deep-seated portions of our globe. Some of the more basic volcanic rocks, derived probably from considerable depths, are known to contain not only a considerable proportion of iron in the combined state, but in some cases also particles of metallic iron occur. The density of the earth as a whole is much greater than that of its surface materials, and this is often regarded as indicating a greater proportion of the heavier metallic elements in its interior; while the magnetic properties of the earth perhaps point to the fact of iron being present there in considerable amount. The melting point of iron also in its pure state is very high (above 4000° F.), and it would be one of the first elements to solidify from a liquid state.

The masses of nickeliferous iron (containing combined carbon) found by Nordenskiold, at Ovifac, in Disco Island, varying in weight from about 20 tons downwards, and which were at first regarded as of meteoric origin, are now generally admitted to be terrestrial products, and were probably brought to the surface with the basalt on, and partly in, which they lay. Careful investigation has revealed smaller metallic masses of similar composition scattered through the basalt of the district. Whether the iron was brought from below in the metallic state, or reduced from some of its compounds by the carbonaceous matter in the lignitic beds through which the lava has passed, is not certain.

This conclusion as to the terrestrial origin of these metallic masses is exceedingly important; not merely in demonstrating the very close connection between deep-seated terrestrial matter and the substance of many meteorites, but also as tending to suggest considerable caution in inferring the necessarily meteoritic origin of

any similar masses which may be met with on the earth's surface, or embedded in the rocks. Another instance of the occurrence of nickeliferous iron derived from terrestrial sources, was observed by Mr. W. Skey, who found in the sand from certain rivers in the South Island of New Zealand, an alloy of nickel and iron, which he compared to the somewhat similar alloy previously met with in the meteorite found in Oktibbeha City, North America. These rivers run from the Olivine range of mountains, which are composed largely of rocks made up of olivine and enstatite (two minerals, be it observed, very common in meteorites), and which rocks are in some places altered to serpentine. In the serpentine, small grains of the same alloy—awaruite, as it has been called—are met with. A paper on the subject by Professor Ulrich, of Dunedin, appeared in the Quarterly Journal of the Geological Society, for 1890.

The natural suggestion has frequently been made that if meteorites contribute in an appreciable degree to the mass of the earth, some record of their presence should be contained in geological strata. With reference to this subject, however, the following considerations should be borne in mind. On account of the very close resemblance between the stony matter of meteorites and many terrestrial minerals, and of the readiness with which such masses would be disintegrated and dispersed, we could hardly expect to recognise any but the largest and most characteristic fragments. And while meteoritic masses composed wholly, or mainly, of metal would certainly be more conspicuous if present in a rock, such meteorites, so far at least as we can judge from our experience of those which have actually been observed to fall, are very much less numerous than those composed of stony matter. Again, our knowledge of the bulk of the matter

constituting the earth's crust is so slight that it would be unreasonable to assert that considerable numbers of meteorites are not contained in the rocks, even though none at all had yet been met with. The studies of the geologist are for the most part confined to mere surfaces—the faces of natural and artificial sections—and the actual amount of material thus visible is infinitesimal compared with the amount which is hidden from his view.

There are, however, several records of masses having been found which are believed to have had a meteoritic origin. Humboldt, referring to this question, says some "problematical nickeliferous masses of native iron have been found in Northern Asia at the gold-washing establishment of Petropawlosk . . . . imbedded 31 ft. in the ground, and more recently in the Western Carpathians . . . . both of which are remarkably like meteoric stones."* Sixteen specimens of native iron (containing nickel, arsenic, and graphite) are recorded as having been found embedded in marl at a depth of 120 feet, while driving a railway tunnel in the Pläner (Cretaceous) beds of Chotzen, Bohemia.† And in the Salsburg museum is a mass of native iron taken from a block of Tertiary coal, which Dr. Gurlt, after a careful examination, came to the conclusion was a true meteoric mass.‡

Bearing in mind what has been said as to the difficulty of recognising such bodies, and also the possibility of a terrestrial origin for some of the metallic masses which have been found, I think we must conclude that,

* Cosmos (Otté's trans.) vol. 1, Note p. 119. A portion of the first of these is in the British Museum.

† Q.J.G.S., vol. xiv., Part 2. Miscellanea, p. 22.

‡ "Nature," vol. xxxv., p. 36.

so far, Geology has little or nothing to say in support of the idea that any appreciable amount of material in this form has been contributed to the strata from extra-terrestrial sources. But neither are we, as it appears to me, in a position to assert positively that such contributions have not, in past times, been made.

It has been contended that, although it may be only in rare instances that meteorites of any noticeable size reach the earth's surface, the number of such bodies which enter the atmosphere, and are dissipated and reduced to the form of vapour or dust, is so great that such a continual rain of fine material must constantly be taking place as must necessarily produce important geological results. I propose, therefore, to summarise briefly some of the facts which have been ascertained about this *Cosmic Dust.*

Perhaps the most accurate study of material ascribed to this source is that by Messrs. Murray and Renard, of the spherules met with in the deep sea material obtained in the "Challenger" dredgings. These authors, in a paper communicated to the Royal Society of Edinburgh* describe two kinds of particles—(1) spherules, generally less than 0·2 mm., having a brilliant black coating of magnetic oxide of iron, enclosing a metallic nucleus consisting of iron more or less alloyed with nickel and cobalt; (2) spherules or chondrules, generally about 0·5 mm., of a yellowish brown colour, with bronze-like lustre, and a lamellar or radiated structure, consisting of bronzite with minute inclusions of magnetite. The close resemblance of these minute particles in mineral composition and physical characters to the larger

* "Nature," xxix., p. 585. Since this address was delivered, a much fuller and more detailed statement of these observations has been published by Messrs. Murray and Renard, in the volume of the "Challenger Reports," dealing with the "Deep Sea Deposits."

meteoritic masses is very marked; and after a careful discussion of the probable sources of such spherules, the authors came to the conclusion that they must be of cosmic origin. It would be interesting to learn of any similar bodies being found in the Chalk, but I am not aware that such has been the case. Messrs. Murray and Renard describe spherules of both kinds as being found associated with and forming part of the concretions of black oxide of manganese and iron oxide, brought up from great depths of the ocean: and Mr. Lockyer, after a spectroscopic examination of such concretionary masses, suggests that the manganese may also, in part, be of meteoritic origin.

A Committee of the British Association some years ago collected records of supposed cosmic particles which had been described from various localities—from the snows of Mt. Blanc, the sediment from rain, &c.; and Dr. Schuster, the Secretary of that Committee, described similar metallic particles which he had found in the sand of the Desert, from near the Great Pyramid.* (A specimen of desert-sand, from the neighbourhood of the temple of Abu Simbel, collected and given to me by our member, Mr. T. Goffey, contains a number of black particles attracted by the magnet, but when examined by the microscope some show the octahedral faces of crystals of magnetite, and all are evidently broken angular fragments, probably derived from neighbouring rocks.)

Baron Nordenskiold has, however, directed our attention most emphatically to this subject and to its possible geological importance. In his work on the "Voyage of the Vega" † he describes how in 1872, to the north of Spitzbergen, he found a layer of snow full

* Brit. Assoc. Report, 1882.

† "Voyage of Vega," vol. i., p. 151.

of black grains, among which were numerous metallic particles attracted by the magnet, and composed of iron, cobalt, and possibly nickel. He estimated the quantity of dust present as from 0·1 to 1 milligramme per square metre of surface (which he says probably does not represent the whole of even one year's fall); and he calculated that, taking the larger estimate, it would give for the whole earth a total amount of about half a million tons per annum. He suggests that continued investigation will, perhaps, show that "our globe has increased gradually from a simple beginning to the dimensions it now possesses; that a considerable quantity of the constituents of our sedimentary strata, especially of those that have been deposited in the open sea far from land, are of cosmic origin." The same observer in his Greenland expedition found a clayey mud (which he called Kryokonite) in circular cavities on the surface of the inland ice, in places where it could not have been washed down from any rocky ridges bordering the glaciers. This Kryokonite was composed principally of terrestrial dust, but comprised also particles of metallic iron containing cobalt and nickel, to which he ascribed a cosmic origin.*

It would seem probable, however, from the observations of other investigators, that Nordenskiold has considerably overestimated the amount and general occurrence of such cosmic particles. For example, Dr. Moss, in describing his investigations as to the structure of the floe-bergs met with in the last English Arctic Expedition, says he found "little granules of dust scattered throughout the stratified ice, all undoubtedly air-carried débris of crystalline rocks."*

* "Nature," vol. xxix., p. 40.

* Nares, "Voyage to Polar Seas." Vol. ii., p. 61.

Dr. Nansen, in the account of his recent journey across Greenland, says, "Of Nordenskiold's glacial dust or cryoconite we saw scarcely anything on the east side; on the west I found it at several places within the last 20 miles, but only in small quantities, though this may be largely due to the lateness of the season, as the holes in which it is usually found were filled and frozen."*

And McGee, in his record in the Smithsonian Report for 1888, p. 254, speaking of Holst's researches in Greenland, says, "Kryokonite was collected in considerable quantity by Holst, carefully examined, and found to contain nothing but the ordinary components of non-eruptive crystalline rocks in finely comminuted condition . . . . but no metallic iron, nor the slightest trace of olivine, augite, or glass were found."

The extraordinary dispersion of the fine material produced by the eruption of Krakatoa, which made itself manifest to us by the magnificent sunsets and other optical effects, should make us careful in ascribing dust, found even in localities far remote from any land, to any but a terrestrial origin. But a careful microscopic examination of such volcanic débris seems to show that the angular particles of glassy material or fragments of crystals (magnetite, pyroxene, felspar, &c.), of which such dust consists, are quite distinct in their characters from the metallic and bronzite spherules before described.

Professor Lockyer thinks that we have some evidence as to the presence of this cosmic dust in the higher regions of the air; for the spectrum of the aurora is markedly similar to that produced when meteoritic matter is subjected to feeble electric currents under conditions of low atmospheric pressure, so that, as he says, "It

* Nansen, "First Crossing of Greenland." Vol. ii., p. 479.

seems probable that the matter which reaches the earth from space is in the main of three degrees of fineness, and gives evidence of its existence at three different heights. The finest furnishes materials for auroral displays at heights reaching to 130 miles; the mean fineness ignites at a height of 75 miles, and gives rise to the appearance of falling stars till a height of 50 miles is reached, when it is all consumed; the coarsest of all at times reaches the surface itself as meteoritic irons or stones."* (Dr. Huggins, however, in his recent address as President of the British Association, regards the theory just mentioned as to the origin of the auroral spectrum as conclusively disproved.)

As to the quantity of this fine material thus added to the earth's mass we have little, if any, trustworthy evidence. From the observations of later investigators which I have quoted, it would appear that the matter is by no means so generally distributed in Arctic Regions as Nordenskiold conceived, and that his estimate of 500,000 tons per annum is thus very considerably too high. But even taking that figure, large as it appears absolutely, when we compare it with known terrestrial quantities we see how relatively small it is in reality. It is only about $\frac{1}{800}$th part as great as the quantity of sediment carried down in the same period by the Mississippi. And as for its cumulative effects, important as they no doubt would be, it would take more than six billions of years to furnish a mass equal to that contained in the sedimentary strata, assuming them to be equal to a shell averaging ten miles in thickness over the whole globe.

But although it seems probable that the amount and geological effects of this cosmic dust have by some writers

* Lockyer, "The Meteoritic Hypothesis," p. 98.

been very considerably overstated, still the evidence in favour of its existence seems quite convincing. And as the metallic spherules to which I have referred are so characteristic, both in form and composition, and so unlike anything known to occur among volcanic dust, or from artificial sources, it is possible that further investigation will reveal the presence of such particles as constituents of some of the more recent deposits.

We may, however, appreciate the difficulty of recognising such material in ordinary sedimentary deposits, when we reflect that, even taking Nordenskiold's estimate, the amount which would fall on the area comprising the basin of the Mississippi would bear to the amount of sediment carried away from that area in the same time the ratio of about 1 to 100,000. It will therefore be seen that only in very slowly accumulated deep sea deposits would there be any chance of readily finding these particles.

And, as I have pointed out in an earlier part of this address, the fact that we have no satisfactory evidence of more than a comparatively insignificant amount of cosmical matter now being added to the mass of our earth does not necessarily prove that the amount was not much greater in past ages, nor does it invalidate a theory that a previous stage in the earth's history was that of a swarm of scattered meteorites. The greater part of the bodies constituting such a swarm might have been absorbed and consolidated long before the strictly geological record began; those since added being either the remnants of the swarm, or altogether independent bodies gathered in by the earth's attraction. We must wait for more light to be thrown on these questions by further investigations. And while, as it seems to me, the geologist is not able to bring much evidence to either

support or refute such speculations, he may regard them with interest, in the hope that a systematic study of other worlds, apparently now in progress of evolution, may throw some light on the history of our own.

The *Nebular hypothesis* of Kant and Laplace as to the origin of the solar system—which has recently received so unexpected an illustration in the structure of the nebula in Andromeda, as shown in the now well-known photograph by our late member, Mr. Isaac Roberts, F.R.S.—is so generally accepted as being, in its main outlines at all events, a very probable history of the formation of the system, that we naturally enquire as to the relation between it and any new scheme of cosmogony. The difficulties which stand in the way of a full acceptance of the nebular hypothesis—*e.g.*, the retrograde motion of the satellites of Uranus, too little difference between the orbital velocity of Neptune and the rotational velocity of the sun, the quicker motion of the inner satellite of Mars than of the planet itself, the divergence of the orbital planes of the planets from the sun's equatorial plane, &c.—while no doubt of considerable importance, are still (neglecting the attempted explanations which have been given) so small in relation to the grand simplicity of the general theory and the many evidences in its favour, that we are not disposed to take kindly to any new hypothesis which does not seem to be in accordance therewith.

The meteoritic hypothesis does not appear to be altogether inconsistent with the nebular hypothesis, and M. Faye has constructed a scheme of cosmogony, starting with the assumption of universally distributed meteorites, and embodying a modified form of the nebular theory for the origin of the solar system. According to Mr. Lockyer's view, one stage in the history of a meteor

swarm (which condenses by virtue of the mutual gravitation between its constituent parts, resulting in collisions and consequent increase of temperature,) is that of a mass of incandescent vapour. Such a mass would probably, on account of a want of uniformity in the bombardment, sooner or later take up a condition of rotation, and we should thus have the rotating nebulous mass with which Laplace started. But, as Prof. G. H. Darwin has shown, it is perhaps not even necessary for the nebular hypothesis that we should have a gaseous mass, all the conditions of fluid pressure being satisfied by a swarm of solid meteorites. And in his well-known theory of the origin of the moon by rupture from the primitive mass of which the future earth and moon were composed, he considered it as at least possible that the moon separated as a flock of meteorites. Many years ago Prof. Clerk Maxwell proved that the stability of Saturn's rings could not be accounted for except on the theory that they were composed of a cloud of separate solid bodies, each moving independently as a small satellite.

In view of recent advances in our knowledge of physics, it has been more than once questioned whether there is any reason to consider that our earth has necessarily passed through a state of actual fluidity. The argument from its spheroidal shape is not conclusive, since we know that even solid matter, under intense pressure, such as exists at great depths in the earth, will under certain circumstances flow until it reaches a state of equilibrium. Mr. T. Mellard Reade, F.G.S., has made use of this principle of the flow of solids in his theory as to the Origin of Mountain Ranges, where he invokes the transference of solid material at considerable depths in the earth's crust to those regions where anti-

clinal folding, due to expansion, has occurred, and thus accounts for the permanency of such features.

Prof. R. S. Woodward, in his address to the American Association for the Advancement of Science, referring to this subject, said: "The conclusion seems unavoidable that at no great depth the pressure is sufficient to break down the structure of all known substances, and hence to produce viscous flow whenever and wherever the stress difference exceeds a certain limit, which cannot be large in proportion to the pressure." And after referring to Tresca's experiments on the flow of solids, he adds:—"With such views and facts in mind, the fluid stage considered indispensable by Laplace does not appear necessary to the evolution of a planet." * And Prof. Haughton has urged several considerations to show that it may be doubted whether the earth or any other planet ever existed in a fluid condition. †

I think I have said sufficient to show you that, in the opinion of competent authorities, whilst it may perhaps be necessary to modify and, to a certain extent, reconstruct the nebular theory in the light of recent advances in knowledge, there appears to be, so far, no sufficient reason why we should reject entirely the principle of that splendid suggestion, which for the first time outlined a system of cosmogony that could be accepted by the scientific investigator, whilst it appealed to the imagination by its sublimity and by the symmetry of its orderly development.

As every advance in our knowledge seems to show only the more clearly the intimate relations that exist between the various bodies of the universe—composed

* "American Journal of Science," Nov., 1889.

† Ibid., Nov., 1882.

apparently of the same kinds of matter, subject to the same great physical laws, and possibly acting and reacting on each other across the almost inconceivable distances which separate them—the geologist should be ever on the alert to avail himself of any results obtained by the workers in other branches of science, which promise to throw any light upon the problems confronting him in his own special subject. And if, as seems probable, we have spread out before us in the star-lit depths of space, not a completed creation but a cosmos in various stages of evolutionary progress, the geological enquirer cannot but regard with special interest the results of that particular science which, in the words of Tennyson,

> . . . "reaches out her arms
> And feels from world to world, and charms
> Her secret from the latest moon."

THE ROUNDING OF SANDSTONE GRAINS OF THE TRIAS AS BEARING ON THE DIVISIONS OF THE BUNTER.

By T. Mellard Reade, F.G.S.

Certain beds of our Triassic Sandstones are distinguished by the extreme roundness of the grains of which they are composed, while most consist of grains considerably rounded, or which have formerly been rounded, though now angular from the deposit of crystalline silica thereon. It has been considered by certain authorities that much of this rounding has been done by wind action, and points to a condition of things which obtains now in dry and desert-like districts and conditions. Others again are inclined to attribute the attrition in most cases to river action, and maintain that such rounding cannot be effected in seas or on shores.

In my paper on the Trias of the Vale of Clwyd*, I have referred generally to the rounding of the component grains of the sandstones of the Vale. On the present occasion I propose to compare those sandstones, generally considered to be the Lower Bunter, with specimens of Bunter rocks from other localities. The localities of the rocks in the Vale of Clwyd are those given in my paper already referred to.

Vale of Clwyd.

1. Quarry south of Llanbedr Farm (east end), described thus in my paper on the Trias of the Vale of Clwyd (p. 284): "Compared with the shore sand at

* Proceedings of the Liverpool Geological Society. Vol. vi, page 3, 1890-91, pp. 278-289.

Blundellsands the grains are on the average smaller but are more irregular in size." The sizes of the grains roughly vary from about 1-75th of an inch down to 1-200th of an inch; they are sub-angular and rounded, some are considerably longer on one axis than the other, some are flatter, especially the smaller grains, of which a certain proportion are well rounded and ellipsoidal in form. Compared with quartzose shore sand from Aberdovey, Mid-Wales, the average size—though the individual grains vary more—is less, the degree of roundness being about the same. This sandstone is used for building purposes, though not very durable. There seems to be little or no deposit of crystalline silica, though there probably is some silica in an amorphous form. The rock after being crumbled between the fingers was treated with hydrochloric acid to remove the dirt and expose the actual form of the grains.

2. River Cliff on the Clwyd (left bank)* opposite Cil Owen. Grains more generally and better rounded and massive than the preceding, with fewer flakes or long grains. They vary in size from about 1-50th to 1-100th of an inch. Rock friable.

3. Railway Cutting under Ruthin Road, south of Denbigh.† The grains average about 1-75th of an inch, being more regular in size than either of the preceding, as well as more regularly rounded, a few being spherical like small shot, the smaller grains being well rounded down to about the 1-120th of an inch. There is no noticeable deposit of crystalline silica.

4. Rock near Foot-bridge over Road from Llanbedr Farm to Ruthin and near Ruthin.‡ Grains more irregular in size and shape than either of the two

---

* Ibid., page 281. † Page 280.

‡ Ibid., page 283.

preceding; a few well rounded, others angular and sub-angular, varying from about 1-60th to about 1 150th of an inch, very friable.

All these rocks are very red and friable, and so mixed up with extraneous aluminous matter and iron oxide as to make it impossible to see the correct form of the grains under the microscope without washing. It is well worth noting that the only one of these rocks fit to be used for building purposes is largely composed of flaky quartzose grains, giving that natural bond described by me in a letter to *Nature*.*

It will be interesting to compare these specimens with similar Bunter rocks from other localities. The type of rock is wide spread in the Trias.

5. Lower Red Rock (Upper Bunter), Guest's Quarry, Runcorn. Large distinct and well rounded grains. There seem to be practically no angular fragments present and scarcely any sub-angular, for though the grains are in many cases irregular in form, they are generally well worn all over. The rock is bright red and crumbly, but does not require treating with acid to show the grains; they stand out distinct and round without it. They vary in size generally from about 1-30th to the 1-70th of an inch.

6. Above this rock, which is considered to be Upper Bunter, comes the Keuper Building Stone, and on the top of this is another friable sandstone, composed of rounded grains not so large or regular as the underlying Bunter, but intermediate in character between it and the Vale of Clywd rocks already described.*

* Vol. xxxvii., pp. 222, 223.

* These rocks have been mineralogically described by Dr. J. S. Hyland in Appendix to my Paper on Slickensides and Normal Faults.—Proceedings of Liverpool Geo. Soc., Session 1888-9, pp. 112-113. Specimens, Nos. 3 and 4.

7. Upper Soft Red, by Grange Grammar School, West Kirby. Well rounded grains, intermixed with irregular-shaped grains, with the edges completely worn round. The grains are very uniformly stained red, but are clean and free from adherent dust or dirt, showing their individual forms well without washing. Resinous lustre, little or no deposit of crystalline silica. Rock friable. Largest grains 1-50th inch longer diameter; smaller grains, 1-150th inch diameter.

8. Holt Cliff, River Dee (south end). Massive extremely well rounded and polished grains of symmetrical shape, measuring from 1-30th to 1-50th inch diameter. No small grains, angular fragments, or dust, colour very red. This is a red pebbly sandstone, and is considered to belong to the Pebble Beds or Middle Bunter.* The grains are the most perfectly rounded of any I have yet examined.

9. Lower Bunter, Bridgenorth, Shropshire. Massive rounded and cubical grains, with the angles worn off. Some of the grains approach the spherical form, and others are elongated; others are irregular, sub-angular, and coated with a fine yellowish-brown rust. There are no pebbles in this rock. Grains more irregular in size and form than those of Holt Cliff; the average size less and more dirt adherent.

10. Naylor's Bridge, Corporation Bore-hole, 342 feet below surface. This rock is now considered to be Lower Bunter, as the Carboniferous Marls were penetrated at 440 feet. On the survey map it is shewn Upper Bunter. Grains of irregular form, some rounded, but the majority angular either from original shape or deposit of crystalline silica, of which there is abundant evidence.

---

* See Hull.

A very fine dust or minute chips of silica adhere to the cover glass as also to the grains. The colour is a dull resinous brown. Many of the grains adhere together after crumbling with the finger, forming composite grains—average size about 1-60th of an inch.

11. Naylor's Bridge, Liverpool, Corporation Borehole, 298 feet below surface. Irregular shaped angular, sub-angular and rounded grains, with a certain proportion of secondary siliceous crystalline growths on the grains. Grains smaller and rather more irregular than No. 10.

12. Bootle Bore, 1146 feet from surface. Lower Bunter? Large pebbly grains 1-20th inch in diameter; some are very well rounded, the majority are in form like well-worn erratics of the Boulder Clay, and might be designated "microscopic boulders." These are mixed with partially rounded grains, averaging about 1-150th inch diameter. There is a good deal of adherent dust and dirt and oxide agglomerating the smaller grains. Some of the grains show characteristic decay, forming depressions below the worn surface, and a little siliceous dust sticks to the cover glass. There also appear to be a few foreign grains of a dark rock. Very irregular angular chips of silica form a small proportion of the grains.

13. Holt Village (Pebble Beds). Large rounded grains (microscopic boulders), individual and distinct, but not spheroidal, mixed with a few angular and sub-angular grains. A small development of siliceous crystal growths and indications of copper in one grain. Differs from No. 8 in the grains being less rounded and covered with siliceous dust.

14. Ness Cliff (Quarry), Shropshire. Bright red, fine grained, Upper Bunter, used as building stone.

The grains are small and irregular in form, a large proportion angular or sub-angular, and a few well rounded but not spherical. Secondary crystal growths.

15. Sand off pebble from Holt Cliff. Similar to No. 13, but larger, more irregular and coarser grains.

16. Conglomerate (Pebble Beds), Burton Point, Cheshire. Large rounded grains, with rough surfaces and a considerable amount of crystal growth, some siliceous dust. Some of the grains are decidedly angular, the original rounding of others is obscured by the growths.

17. Conglomerate (Pebble Beds), Market Drayton, Shropshire. Similar to No. 16, but rather smaller in grain.

18. Bank Hey Delf, Tarbock. Lower Bunter. Distinct well rounded and partially rounded grains. Microscopic boulders with adherent dirt and eroded surfaces.

19. Wallasey Bore-hole, Cheshire. Upper Bunter. Very small irregular rounded grains intermixed with decidedly larger individuals, some of which are smooth and well rounded, and others eroded but with smooth surfaces. Some of the smaller grains are crystalline and sharp.

20. Heswall Sewer, Cheshire. Soft Upper Bunter Sandstone, in which the trench was excavated. Grain similar to No. 19, but larger, more coated with hydrate of iron, and less crystalline.

21. Hard sandstone blocks (Keuper) lying bedded in an alluvial deposit overlying the above, not easily distinguished as separate from the underlying rock, but unmistakably so on careful examination. Supposed to be remains of a hard Keuper Stone capping.

Some large well rounded grains, but most of them highly crystalline and facetted. A much more crystalline sandstone than any of the preceding 20 specimens. The stones were so hard that the contractor tunnelled under them where he could. A good many grains show evidence of having been well rounded, but in many it is obscured by crystalline growths.

22. Keuper Sandstone, from near Waterworks, West Kirby, Cheshire. Well developed grains, with much crystalline growth, and grains cemented together consisting apparently of quartz in different conditions. Some of the grains are sugary looking, and apparently undergoing decomposition, while the crystals are translucent, and the colour of sugar candy. The grains separate pretty freely from the rock. The grains are sometimes united in aggregates. The white grains are quite apparent in the rock, giving it a speckled appearance.

23. White Building Stone, Makinson's Quarry, Storeton, Cheshire. The grains are smaller than No. 22, and of pretty regular sizes. Some of the grains remain as aggregates after the rock is reduced to powder between the fingers. The original rounding of the grains is rendered obscure by crystal growth. There are many snowy white grains having a sort of fibrous structure. There is also this frosty appearance on portions of the translucent quartz. It seems to be the breaking up of these grains that supplies the secondary silica.

24. Keuper Building Stone, No. 1 Quarry, Town Green, Lancashire (bottom bed). White translucent quartz grains. Some of these grains show much rounding, but are covered with minute spangles of quartz like what occur sometimes on the large pebbles of the

Pebble Beds. Some of the grains are almost crystals, and many well facetted. There are but few of the white sugary-looking variety—not so many cemented aggregates as in 23.

25. Keuper Building Stone (white), Edge Quarry, Edge Hall, near Malpas, Cheshire. This is an exceedingly hard sandstone, used for steps and similar purposes. The grains are irregular in size and shape, some of them are of the white sugary variety. There are aggregates of grains quite translucent and perfectly cemented together like groups of crystals. There is a large development of secondary quartz.

26. Keuper Sandstone, road cutting over Overton Scar, Cheshire. This is mottled red and white. A is from the white patch. It is not a pure white like the last—some of the grains are coloured. One of the largest grains shows a parallel fibrous structure and some others show the same. There is a development of secondary silica, also grains of kaolin. B, Red variety taken from within a couple of inches of No. 26 A. The grains are stained with peroxide of iron, and there is not so great a development of secondary silica; in other respects like 26 A.

27. Keuper Sandstone, lane from Malpas to Overton Scar. Rounded and irregular grains, deeply stained with iron oxide. Not much development of secondary silica. A friable stone of a deep red.

28. Hard bed in Keuper Building Stone, near bottom of Quarry, Norton, Cheshire. There were a few dark quartzite pebbles in this bed. Large boulder-like looking grains, covered over with small spangles and facets. Some of the grains show the silica breaking up in the sugary form, but only a small proportion.

29. Conglomerate in Pebble Beds, sewer cutting, Church Road, Walton. This was a terribly hard rock, full of a variety of pebbles, igneous and otherwise. The grains are white quartz, angular and sub-angular, and none have smooth worn surfaces, but have probably been partially rounded and then chemically eroded. They are covered with the frosty or sugary deposit of silica in a dusty form. White mica present. There are white sugary grains, but not much crystal growth and facetting.

30. Upton Rock Quarry, Lancashire (near Widnes), Pebble Beds. Rounded pebbly-looking grains, with irregular shaped grains intermixed, some growth of crystals, and the whole covered with pellicles of peroxide of iron. Grains cemented together in aggregates.

31. Appleton Quarry, Lancashire. Pebble Beds. Similar to No. 30, but smaller in grain.

32. Pex Hill Quarry, Lancashire. Pebble Beds. Much larger grains than No. 30, rather more crystalline, but in other respects similar. Nos. 30, 31 and 32 are all undoubted Pebble Beds, so far as being full of the characteristic pebbles makes them so.

33. Alderley Edge. Cupriferous Sandstone, Keuper. Small well-rounded white grains of quartz, between translucent and sugary, intermixed with small coppery green grains. A pretty object under the microscope.

If the preceding examples are to be considered fair representatives of the Triassic Rocks, we may separate them into two broad divisions, or types distinctive of the Keuper and Bunter.

The Keuper Sandstones, as a whole, are much less

rounded in the grain, and there has been considerably more deposition of silica and crystalline growth.* The irregularities of the grains are partly due to this fact, but I think that any unbiassed observer will say that the Bunter Sandstones show evidences of much severer wear and attrition.

Although there are some deep-red Keuper Sandstones—notably some of the beds near Malpas, in Cheshire, and the bed overlying the Runcorn building stones—as a rule the Keuper Sandstones are of a lighter tint and are often grey, or white, or light yellow. It is this crystalline character that renders the Keuper more frequently suitable for building stone, though in our own neighbourhood there are beds of the Bunter, such as those at Woolton, Rainhill, and Everton, that in some respects surpass the Keuper. In these cases there has been a large development of secondary silica, and the sandstone is of a more crystalline nature. In some of the exceptionally hard beds this crystalline character has been carried still further.

If we take the Bunter Sandstones as a whole, we find that, as I have before stated, the grains have been considerably worn. It has been thought—it is in fact generally believed—that the lower beds of the Bunter are distinguished by larger and rounder grains than the rest of the rock. Against this we have the fact that the Vale of Clwyd rocks, considered to be lower Bunter, are rather small in the grain, and not nearly so much

* Our Secretary has called my attention to the fact that Darwin in his Geological Observations, published in 1844, notices that the sandstones of the Blue Mountains, New South Wales, often have their grains crystallised, and suggests that it may be due to the rounded grains of quartz having been "acted on by a fluid corroding their surfaces, and depositing on them fresh silica." He also points out that William Smith had noted "that the grains of quartz in the Millstone Grit of England are often crystallised."

rounded as many of the Upper Bunter rocks. The Lower Bunter of Bank Hey Delf, No. 18, is of a larger and rounder grain. Neither the Corporation Bore-hole at Naylor's Bridge, Nos. 10 and 11, nor the Bootle bore, No. 12, throw much light on this question. The former was considered at the time to commence in the Upper Bunter (the beds being so classified in the Geological Survey Map) but as at a depth of 440 feet the boring tools went through marl, evidently belonging to the carboniferous system, the theory had to be modified. The rock is not at all distinguished by roundness of grain in either of the samples described, and this has led some geologists to class the lower sandstone as "Pebble Beds" (without pebbles) and to assume the existence of a fault which cut off the Lower Bunter, and which the boring tool penetrated till it reached the Carboniferous Marl.

It appears to me that this is making further and unnecessary difficulties to uphold the theory. The Bootle bore, No. 11, showed at 1,146 feet deep large round grains, but they are not at all typical examples of the rounded or "Millet Seed" Sandstone.

Again: No. 14, Ness Cliff, Shropshire, is Upper Bunter, typical so far as general appearance goes, but the grains are small and irregular.

No. 7, Upper Bunter from Grange, West Kirby, has well rounded grains of medium size. No. 5, Upper Bunter, Runcorn, is perhaps the best example of extreme and general rounding of large-sized grains in this division. If, however, we compare this example with No. 8, from Holt Cliff, undoubted "Pebble Beds"—if pebbles have anything to say in the question—we find that the grains of this specimen excel all those in my list for extreme rounding and polishing. That this is

not a solitary fact we may discover by examining specimen No. 13, from Holt Village, on the same Pebble Beds, but a considerable distance off. The Lower Bunter from Bridgnorth is a good example of the characteristics that are supposed to distinguish the Lower Bunter.

The Pebble Beds (full of pebbles) in the Quarries at Appleton, Upton, Pex Hill, and the district generally between Rainhill and Widnes, contain a large proportion of rounded grains, and differ from the typical Upper and Lower Bunter, principally through the greater deposition of silica that has taken place, which has converted the rock into building stone. But this conversion has taken place in cases where pebbles are certainly absent, in which cases we have the anomalous pebbleless "Pebble Beds." In the Pebble Beds at Burton Point, Cheshire, a typical section (see p. 40, Hull's Memoir on the Triassic and Permian Rocks of the Midland Counties), large rounded grains are present (No. 16), though the considerable development of secondary silica has converted the rock into a building stone (the old promenade sea wall at Parkgate is certainly built of this stone), and in other cases such as that at Church Road, Walton, the cementation of the grains has been carried still further (29).

From these various considerations I am led to believe that the Pebble Beds, though in many instances overlaid and underlaid with soft red sandstones, occur at various horizons in the Bunter. If, as I maintain, the distinguishing characteristics of the building stones of the Bunter, nearly always classed as Pebble Beds, have arisen from secondary causes long since their deposition, it seems unlikely that this influence should have been exerted only on the middle of the series

throughout a large area of hundreds of square miles. The Pebble Beds of Chester are notoriously unreliable as building stone. That pebbles are not a reliable indication of the horizon of the bed they occur in is plainly shown by their frequency at Holt, in Cheshire on the cliff section by the River Dee, which Professor Hull says is near the base of the Bunter. Where pebbles are found in the rock near the surface it is open for anyone to allege that the Upper soft beds have been removed. There is a case however at Hilbre Island, at the mouth of the Dee, which I believe proves my point, that pebbles occur in the Upper part of the Bunter also.

This section has, I feel pretty confident, been misinterpreted hitherto. The capping of rock is in my opinion typical Keuper Sandstone, which I have traced almost to Little Eye, until it is cut off by a fault. I will give further evidence of this in a separate paper.

We are thus driven to the belief, that neither the crystalline character of the Bunter Sandstone, nor the presence of pebbles are any reliable indication of the horizon they occur in, nor are the two characteristics otherwise than separable. The Bunter Sandstones are a great group in which, from whatever cause, there has been a large impregnation of ferric oxide, and other impurities which have in the majority of cases interfered with the deposition of secondary silica. The grains have also been laid down in turbulent conditions of current, evincing long travel of an oscillatory or tidal character, according to my view.*

The Keuper Sandstones are much freer as a rule from extraneous matter, and to this cause it is reasonable to attribute the greater decomposition and recomposition which has taken place in the siliceous constituents.

---

* Physiography of the Lower Trias. Geo. Mag., 1889, pp. 549, 557.

MUD AVALANCHES.

By E. Dickson, F.G.S.,

With Note by Linnæus Cumming, M.A.

In the early spring of 1890 I was staying in the Rhone Valley, and on a day in the middle of March attempted to walk over from Martigny in the Rhone Valley to Argentière in the Chamouny Valley. The route I chose was the well-known one over the Col de Balme, a route of no difficulty in the summer months, but at that time of year, as I found, practically almost impassable. I was however rewarded for the very considerable effort that such a walk entailed by meeting, at a point about 1,000 to 1,500 feet above Martigny, with a "Mud Avalanche." At first I could hardly trust my own eyesight, for it seemed as if a part of the hill side was in motion. It was, in fact, a stream of mud slowly descending the mountain side, carrying on it and in it stones and boulders.

The sight led me to consider, first the causes, secondly the effects of such a phenomenon. The initial cause would seem to be the frozen sub-soil, which prevents the melted snow and rain from percolating through the ground, as it would be able to do a month later. Again in the Sub-Alpine and Mid-Alpine districts, the snow, when it begins to melt, does so very rapidly, and if to the sun's power is added torrential showers, there are ready to hand the main causes for producing a mud avalanche. The frozen sub-soil of the mountain side is by these agencies converted into a slimy mud, which frequently descends with resistless force and carries with it destruction far and wide. But there is another element to be taken into account, and that is the character of the rock beneath the sub-soil; for if the

rock is of a crystalline character (supposing the other causes to be present), then probably mud avalanches would be practically unknown; but if, as is the case with the Dent du Midi, the rock is of a shaly character and constantly crumbling to pieces, abundant material is supplied for the formation of mud avalanches on a large scale, and such is found to be actually the case. In the same Rhone Valley, the plain below the Dent du Midi—not far from St. Maurice—is covered with huge blocks of stone and débris left by a gigantic stream of mud, which, in August 1835 flowed from the Dent du Midi and devastated the whole valley. A more complete scene of desolation it is hardly possible to witness. There are records to show, that one of these mud avalanches many centuries ago descended the same mountain and utterly wiped out one of the towns in the valley. Now these stones are not all stones from the neighbouring mountain, but consist of granitic, gneissic, and other erratic blocks, their presence here being due to the fact that these mud avalanches carry with them, not merely local, but also foreign débris carried to the mountain slopes by direct glacial agency at a much earlier period. The appearance of this portion of the Rhone Valley very closely resembles that of any valley from which a glacier has retreated, and anyone seeing the masses of blocks, sand, and gravel in that part of the valley near St. Maurice, would have good apparent reason for ascribing their mode of origin to direct glacial agency.

The effects of mud avalanches considered as geological agents, are by no means unimportant.

Many of the valleys in the Alps, except where the mountains which bound them are composed of crystalline rocks, bear traces of the destruction wrought by the

mud streams. Terrible as the snow and ice avalanches most undoubtedly are, I very much question if their permanent destructive effect is to be compared with that produced by mud avalanches. On the Italian side of the Alps, more than on the Swiss side, occur heaps of débris, which at first sight would naturally be put down as moraines, but which really owe their origin to mud streams.

One characteristic and important effect of the "mud avalanche," is the clean sweep it makes of all the loose material composing the upper layers of the rock over which it flows, thereby exposing the latter to fresh atmospheric attack; the mud-borne débris ultimately finding its way into the valley, where it is deposited in the roughly formed mounds in which we find it. On the slopes of the mountains forming the Rhone valley occur also heaps of true morainic matter deposited by the great glacier which in the glacial period almost filled up the valley, and this material the mud streams carry along with them, until the whole, after becoming mixed with the strictly local débris, is finally deposited in the valley.

Again, these mud streams after descending a mountain very frequently find their way into a bed of a stream as offering a path of least resistance, the usual result being to dam up the stream and and eventually to produce a flood more or less disastrous to the surrounding district.

Not unfrequently as the result of the damming up of a stream by a mud avalanche is the formation of what may be termed a secondary mud avalanche, less severe in its effects, and due to the breaking up of the partially consolidated mud of the original incursion by the water behind it. Thus may the remoter parts of the valley be

invaded with erratics and detritus that once formed part of the primary downflow. A well-known instance of a mud stream so formed is the one which so nearly destroyed the town of Cortina in 1842.

In the majority of cases, however, these mud streams do not find their way into or across any river course, but descending the mountain slope form more or less irregularly rounded mounds at the base of the slope and frequently in the valleys below. In Swiss valleys one frequently sees mounds of débris, differing in size and composition, the origin of which one would naturally ascribe to glacial action.

In addition to mud avalanches there are at least four different agents capable of producing "mounds" of débris.

There are, of course, those heaps of débris which undoubtedly owe their origin to ice action, and are really "moraines." There is no necessity to say much about them, as "moraines" have been the subject of Papers read before this Society in recent Sessions, and I will only call attention to the fact that lateral moraines are often present on a very steep slope owing to the fragments being cemented in a hard matrix, and that terminal moraines "roughly rounded heaps of fragments of all sizes pitched together with no regularity or semblance of order," are, so far as my observation goes, characterised by a remarkable absence of fine sand, earth, or mud, which I think, one usually does find in those heaps in this country, which are considered to be and commonly called "Moraines." My experience coincides with that of Mr. Cumming as expressed in his Paper on "Moraines" (vol. vi., p. 187), that "remains such as anyone familiar with glaciation abroad would at once recognise as moraines, are very rare in this country."

Another instance of mounds of débris occurring in the valleys, and in their general appearance resembling "Moraines," is that of mounds formed by "Berg falls." These "Berg falls" chiefly (though by no means exclusively) occur in those cases where the rocks are of a shaly character, as for example the Dent du Midi, where after heavy rains, sudden thaws, or earthquakes, cataracts of rocks fall into the valleys. In 1855 showers of stones fell for weeks and months, the débris accumulating to such an extent as almost to block up the side valleys leading into the Rhone Valley, and, indeed, along the whole of the Rhone Valley occur heaps of débris due to "Berg falls," of considerable height and extent. These "Berg falls" also occur where the rocks consist of chalk, oölite, or dolomitic limestone, and which offer small resistance to the chemical and mechanical action of water. Thus, in the case of the Diablerets Mountains, two of the peaks or teeth fell in the last century, and their fragments cover an area of several square miles.

Mount Calanda above Chur, supplies another example of the manner in which heaps of débris may be formed by a cause other than glacial agency. This mountain is formed of fissured dolomite resting upon beds of soft rock incapable of resisting the action of denudation. The waste washed down from the mountains has formed huge sloping mounds at the foot of the cliffs, constituting a characteristic feature of the landscape.

Another agent, which possibly more than any other is responsible in mountainous districts for a large number of the heaps of débris so frequently met with, is floods. In the Alps generally, and on the Italian side more especially, are to be seen great masses of débris

which have been carried down by the torrents due to the sudden melting of the snow. I think that anyone seeing these great masses in the Lombardy plains would naturally consider them as true moraines. The blocking-up of streams by glaciers and morainic material, as in the case of the great Dranse flood in 1818, by berg falls, by mud streams, by the sudden melting of the snow, by the retreat of glaciers freeing water flowing down tributary valleys, all help to produce floods, and all help to bring about the same result. Many of these floods become veritable mud avalanches, mixing together débris from the berg fall and morainic matter from the glacier, and not unfrequently complicate matters further by carrying with them morainic matter left by the glaciers of the glacial period. Such heaps are met with in the Adige valley, and more especially in the valleys and plains on the Italian side of the Alps. Some estimate of the amount of the débris carried into the Lombardy plains by the rivers may be formed from the statement that its depth is estimated at 4,000 feet, and its volume as equal to that of the existing mountain systems.

I will in conclusion refer to those low ridges of sand or shingle, varying in height from 20 to 200 feet, known as ăsars, occurring in Scandinavia, and which sometimes extend for seventy miles. These ăsars were first supposed to be true moraines, but it is now generally I think admitted, that the material composing these ăsars was transported in the first stage by ice, and then carried further by other geological agencies; and such I take it has been the case with many of those heaps occurring in Swiss and Italian valleys, and which, at first sight, would naturally be put down as true moraines. If this be the case with heaps of débris in Swiss, Italian, and Scandinavian valleys and plains, why

should not similar causes have at times operated to produce these heaps of débris in our own country, which perhaps sometimes too hastily have been considered as true moraines, and due entirely to ice action.

Note by Linnæus Cumming, M.A.

On the 22nd and 23rd of last August I had occasion to cross the Stelvio Pass, from Italy into Austria. The weather on those days, as well as on one or two preceding them, was extremely wet, and had led to the lateral streams pouring down from the hill side becoming much swollen and turbid. In some cases large streams swept down from gullies which must have been ordinarily dry, as was proved by the entire absence of culverts to carry the water under the roadway. In consequence these streams invaded the roads and men were engaged pushing up artificial wooden embankments to limit the channel of the torrent and prevent a widespread destruction of the road.

In connection with many of these streams, both North and South of the pass, large heaps of material had been brought down by the torrents, blocking up the roadways and lying on both sides of it. The heaps consisted of mud mixed with fragments of rock of various sizes, from very small particles up to pieces weighing two or three pounds. These fragments were rough and angular, showing no orderly arrangement as far as I could discern. The general outline of these heaps was cone or fan-shaped, the vertex of the cone lying in the small gully, and the base spreading over the road and hillside.

The manner in which the mud cones are formed is not far to seek. The downward rush of water loosens

first the surface of soil in which the stones are held, and stirs it up into the water, making it highly turbid. The removal of the earth loosens the stones, which are now driven along with the torrent and held supported in the water rendered specifically heavier by admixtures of large quantities of mud. The material is dropped where the speed of the torrent is checked, as by the level roadway, but before it has completed the crossing of the road the stream has begun its work again, cutting a deep gully before it in the material of the roadway itself.

After reading the foregoing Paper I see that the phenomenon, observed by me and described above, is not absolutely identical with the "mud avalanche" of Mr. Dickson, which strikes me as being little, if at all, different from a landslip, and brought about by much the same causes. I have seen exactly the same thing, on a very small scale, in one of the cuttings of the canal within two miles of Rugby, and I believe that the landslips which occur from time to time on railway cuttings are of that nature. I attribute them to the water formed by melting snow and rain being unable to percolate through the frozen subsoil, and finding its way by gravitation into cuttings, where it saturates the surface soil, converting it into soft mud, whose natural slope is much smaller than that of the bank. The whole mass consequently begins to move forward and covers the floor of the cutting. The same thing may occur in times of flood, when the lie of the strata concentrates the drainage of the soil at certain localities.

The formation I have described I should rather call mud cones or mud fans, and is, I believe, formed by torrential streams, which sweep down steep hills whenever a heavy rain occurs. Some of the mud

mounds of Mount Callenda and of the Italian side of the Alps, described by Mr. Dickson, I am inclined to attribute to this cause rather than to berg falls; but without examination on the spot it is impossible to be certain.

The mud cones, consisting largely of dislodged fragments of rock, would contain an admixture of undoubted ice-borne rock masses which were left perched on the hill side by the melting of ancient glaciers. It seemed to me that a number of these cones from different gullies would form a continuous fringe along the side of a steep valley, which fringe composed of stones from varied sources, sand and mud collected without appearance of stratification might easily be mistaken for an ancient lateral moraine *in situ*. The main distinguishing features would be the presence of much mud and water-worn sand, the absence of sharp glacial sand, and the partial rounding of the included rock masses, which would not, however, be water-worn, but only slightly abraded at the edges. I think the mud avalanche would more closely resemble a terminal than lateral moraine.

The subject of redistributed glacial material which fills every Norwegian valley needs further consideration than can be given here.

F.

REPORT ON THE GLACIAL DEPOSITS BETWEEN DINGLE POINT, LIVERPOOL, AND HALE HEAD.

By Joseph Lomas, Assoc. R.C.S.,*

Special Lecturer on Geology, University College, Liverpool.

At Dingle Point the picturesque cliffs of Upper Bunter Sandstone are capped by a few feet of Boulder Clay. A little distance past Southwood Road we leave the sandstone, and a cliff of Boulder Clay, about 30 feet high comes in. The lower portion is sandy, and contains many scratched stones. Patches of gravel occur in the clay, and they frequently have a vertical direction. The upper portion is also a clay, columnar, darker in colour, and less stony.

Beyond Fulwood Park, on the Otterspool shore, Boulder Clay cliffs come in again. These have been described by various observers. In the "Geology of Liverpool," p. 214, three sections are given at different points along this shore.

	St. Michael's.	Old Limekilns.	Jericho Shore.
Upper Boulder Clay	10 feet.	17 feet.	14 feet.
			Parting and line of Boulders.
			6 feet.
Middle Sands.	Parting.	Line of Boulders.	Parting.
Lower Boulder Clay	20 feet	18 feet.	15 feet.
	30 feet	35 feet	35 feet.

It is difficult to interpret these sections on the theory of the tripartite division of the glacial deposits. The partings and lines of boulders cannot represent any definite horizon of time, for they are not constant, even over small areas, and according to Mr. Morton "just beyond" [the Jericho Shore] "the Lower Red Clay

* Made by the Boulder Committee appointed by the Society, and embodied in the Report presented by the Committee of the Society, Dec. 8th, 1892.

becomes gradually blended with the Upper Brown Clay, and there was either no pause between the deposition of the beds, or the surface of the lower bed was worked up and mixed with the upper one along the line of separation." Cliffs of Boulder Clay appear just beyond Garston, and continue with but little intermission to beyond Hale Head.

Near the Battery at Garston the clay in the cliffs is about 14 feet high, and the base is not seen. It is of a sandy tough nature. The stones are well rounded, and the clay is columnar. At intervals a layer of gravel appears, usually overlaid by a fine laminated clay, about 8 inches thick. Near the targets the clay is only about 4 feet high, but there is an increase in the thickness of the river sand which covers the clay all along the section from Dingle to Hale Head.

Beyond the targets the lower part consists of a hard sandy bed, with many stones, and above are 14 feet of stiff clay. The clay a little further on becomes very shelly. It is literally crowded with shell fragments, and is in striking contrast with other parts of the section, where shell fragments are very scarce. At this place there is a good example of the "forced" arrangement of boulders. The long axes of the small boulders are all arranged at an angle of 45 degrees, and their flat faces are turned upwards towards the N. The normal to the plane in which the stones lie would indicate the direction of the force which arranged them. The cliffs are continued past Speke Hall, to the Dungeon, but for a considerable distance the lower beds are obscured by landslips. At Oglet Point we have a section :

20 feet columnar clay, with many boulders.
4 inches laminated clay.
4 feet tough sandy clay, with few pebbles.

The line of laminated clay is well marked. It is straight, but not horizontal. A little further S. the *lower* bed is columnar (this shows how little structure is to be depended on, in correlating these beds). It is overlaid by 1 foot of stratified clay, which bends in a gentle curve in a trough-like form, and is overlaid by 40 feet of clay, with few boulders. Near this a bed of sand suddenly comes in. It is beautifully stratified. Examined microscopically it is moderately well rounded, and contains minute shell fragments. The sand is almost undistinguishable from our local shore sands. Further on, the sand thickens suddenly, and contains a triangular mass of dark red sand, with angular fragments of local red sandstone. The laminated clay here has a thickness of 10 inches, and curves round the sand as it changes in altitude.*

According to Mr. Strahan, F.G.S., the surface of the laminated clay is ripple-marked a little further on, near the Dungeon.

Beyond the Marsh the Boulder Clay again is seen. It is continued to a point about 100 yards E. of the Crow's Nest or Gorse Clump. The clay, which is very sandy, is 20 feet high, and is overlaid by 4 feet of yellow sand.

After a short interval the clay comes in again opposite a group of three trees. About 4 feet of a sandy

---

* The overlying of interbedded sands and gravels by finely laminated clay is of almost constant occurrence. Two causes may have operated to produce this result:—

(1) In places where the sands act as a channel for the flow of underground water, there would naturally be a filtering process going on, and the clay might represent the residue from such an operation.

(2) The sand, being laid down under water, represents a certain rate of flow. If this became diminished, only the finer particles would be carried along and deposited. The Boulder Clay above would then represent a state when no water at all was present. The ripple-marked surface, described by Mr. Strahan, might be due to this cause.

stiff Boulder Clay is exposed, overlaid by river sand. The clay contains numerous small boulders, nearly all striated. About 100 yards from this place a lower bed of extremely hard sandy clay is seen, and it extends 95 yards, varying in height from 4 inches to 6 feet. It is exposed again on the shore, riverwards, at a depth of 22 feet below the base of the cliff.

The beds are now obscured for a short distance, but on reappearing the Pebble Beds of the Bunter are seen with a thin capping of Boulder Clay. At places, a line of boulders lying directly on the Pebble Beds, is all that exists of the glacial deposits.

The sandstone increases in height towards the lighthouse, and consists of bosses with the hollows filled in with Boulder Clay. Beyond the Lighthouse the sandstone decreases in height and is succeeded by cliffs of Boulder Clay.

800 yards W. of the Lighthouse, about the middle of the second boss of rock, there is a bed in the sandstone consisting almost wholly of white quartzite pebbles. It is inclined at a high angle. At the surface the pebbles are seen to be pulled over in a S. Easterly direction, while none are to be seen on the N.W. side of the outcrop.

In the same boss, just before the fence is reached, there is a band of sand and clay containing Northern erratics, overlaid by a large piece of sandstone which, at first sight, appears undisturbed; the bedding planes run exactly parallel with those of the rock beside it. The erratics show the "forced" arrangement, and the tongue of clay has evidently been pushed from a North or North-Westerly direction.

Only a few yards nearer the Lighthouse there is a fine example of a ground moraine. Angular pieces of the

neighbouring Pebble beds are mixed up most intimately with Northern rounded Erratics. Gravel patches too occur which have mostly a vertical direction.

The surface of the rock all along is broken up into angular pieces, and erratics are frequently found mixed up with them.

A list of the Boulders lying on the shore is appended. With few exceptions only those have been recorded which measured at least 20 inches in one direction.

A very large proportion of these boulders are planed and striated. It is almost always the case that the upper and lower surfaces are striated in opposite directions. Only one exception was noticed, in a group near Fulwood Park. The striations are nearly always parallel to the long axis of the stone. A fair number are pear-shaped, and the blunt end almost invariably faces the North.

In the section between Garston and Hale Head special attention was paid to the direction of the long axes of the boulders, in cases where they had obviously not been moved.* At Garston 10 out of 11 had their axes N. and S. One was E. and W., but was striated N. and S. Near Hale out of 22 recorded 12 were N. and S., 5 N.W. and S.E., and 5 in other directions. It is interesting to note the gradual change of the axes towards the West as we approach Hale Head. A little further on at Runcorn, the glacial striæ run almost E. and W. At Hale there were several boulders *in situ* in the cliffs, and their striations exactly corresponded in direction with those of the boulders near them on the shore.

Near the Targets at Garston there is a group of four boulders (Nos. 98-101). Three have their

* In cases where the length and breadth are almost equal it is difficult to say which represents the axis.

axes N. and S. and the fourth E. and W., but it is striated from N. to S. like the others. Their upper surfaces are about in the same plane, and they may be regarded as constituting a "striated pavement."

The largest boulder met with is on the Jericho shore, a little beyond the stream. It is partially buried in mud, and measures 8 feet by 4 feet 4 inches, by 1 foot 4 inches visible. Opposite Hale Lighthouse there is one measuring 7 feet by 2 feet 6 inches, by 3 feet 4 inches, and near the Dingle there are several about 5 feet long.

Out of 135 large boulders 58 or 43 p.c. are Lake District Andesites.
51 or 38 p.c. are Scotch Granites.
9 or 6½ p.c. are Silurian Grits.
6 or 4½ p.c. are Diorites.
No others over 2 p.c.

Taking the shore in two sections we have

From Dingle to Garston	From Garston to Hale
46 per cent. Andesites.	38 per cent. Andesites.
28 per cent. Scotch Granites.	54 per cent. Scotch Granites.
9 per cent. Silurian Grits.	2 per cent. Silurian Grits.

3 Limestones, 1 Eskdale Granite, 1 Felsite, and 1 White Sandstone, have been noticed among the large boulders. Among the smaller ones we have Buttermere Granophyre, Flints, Antrim Chalk, and 6 specimens of the Riebeckite Eurite from Ailsa Crag. One of these was found at the Dingle, 2 at Garston, and 3 at Hale Head. Ripple-marked Sandstones are met with, and marls with rock salt pseudomorphs.

LIST OF BOULDERS OCCURRING ON THE SHORE.

[The measurements are given in inches.]

1	Between Herculaneum Dock and Dingle Point.	35 by 28 by 18....	Andesite, Pear-shaped, well rounded.
2		31 ,, 21 ,, 15....	Silurian Grit.
3		39 ,, 39 ,, 22....	Andesite, well rounded, polished and grooved at top and sides.

4	Group in first creek beyond Dingle Point.	59 by 49 by 42	....Andesite, rounded.
5		27 ,, 23 ,, 21	....Andesite, rounded.
6		33 ,, 27 ,, 13	....Criffel Granite, tabular in form.
7		31 ,, 28 ,, 20	....Criffel Granite, rounded.
8		56 ,, 42 ,, 24	....Scotch Granite, pear-shaped, well planed and striated.
9		23 ,, 17 ,, 14	....Dalbeattie Granite, rounded.
10	Group about Knotts' Hole.	55 ,, 42 ,, 30	....Andesite, well rounded.
11		54 ,, 39 ,, 32	....Felsite, well rounded, striated axially.
12		42 ,, 26 ,, 18	....Andesite, rounded, striated.
13		23 ,, 18 ,, 8	....Andesite, well rounded.
14		39 ,, 39 ,, 24	....Diorite, weathers in rounded nodules and flaky.
15		51 ,, 25 ,, 25	....Andesitic Agglomerate, well rounded, beautifully polished, and striated on all sides.
16	Between Knotts' Hole and Southwood Road.	31 ,, 29 ,, 17	....Scotch Granite, polished on one face.
17		33 ,, 18 ,, 13	....Scotch Granite, sub-angular.
18		31 ,, 24 ,, 12	....Grit, polished and planed on upper surface, striated axially and at right angles to axis.
19		54 ,, 28 ,, 14	....Dalbeattie, tabular in shape.
20		40 ,, 31 ,, 20	....Grit, well rounded, beautifully polished.
21		18 ,, 15 ,, 10	....Andesite, polished and striated.
22		25 ,, 22 ,, 16	....Andesitic Ash, well rounded, polished.
23		16 ,, 12 ,, 18	....Silurian Grit, rounded, striæ run axially from blunt to pointed end.
24		37 ,, 27 ,, 20	....Ash, well rounded, polished.
25		50 ,, 40 ,, 16	....Grit, tabular, planed and grooved axially.
26		46 ,, 22 ,, 22	....Dalbeattie, rounded, pear-shaped, blunt end fractured, polished.
27	Opposite Boulder Clay Cliffs, Fulwood Park.	21 ,, 20 ,, 13	....Andesite, beautifully polished and striated at right angles to axis.
28		16 ,, 12 ,, 12	....Diorite, nodular.
29		24 ,, 13 ,, 12	....Andesitic Ash, polished and striated axially on upper and lower surfaces.

30	Between Fulwood and Otterspool.	23 by 12 by 17	....Andesite.
31		21 " 14 " 12	....Andesite, well polished.
32		23 " 15 " 12	....Andesite, well rounded, striated axially.
33		24 " 16 " 16	....White Sandstone, tabular.
34		31 " 20 " 12	....Andesitic Ash, rounded striated obliquely to axis.
35		17 " 13 " 13	....Limestone.
36		24 " 16 " 13	....Andesite, conical shaped.
37		17 " 13 " 13	....Silurian Grit, sub-angular.
38		18 " 17 " 16	....Yewdale Breccia, rounded.
39		18 " 18 " ?	....Andesite.
40		22 " 16 " 9+	..Dalbeattie Granite, tabular.
41		20 " 12 " 12+	..Andesite, rounded and smooth.
42		27 " 12 " 12+	..Scotch Granite, rounded and smoothed.
43		30 " 16 " ?	....Ash.
44		24 " 15 " 10+	..Andesite, vesicular, rounded
45		29 " 21 " 12+	..Dalbeattie Granite, tabular, planed.
46		29 " 18 " 10+	..Criffel Granite, tabular, smooth.
47		24 " 11 " 11+	..Andesite.
48		25 " 21 " ?	....Yewdale Breccia, tabular, well polished.
49		26 " 18 " 12+	..Andesite.
50		33 " 20 " 20+	..Criffel Granite, rounded.
51		56 " 36 " 22+	..Yewdale Breccia, tabular, rounded.
52		31 " 31 " 20+	..Dalbeattie, tabular, well polished.
53		29 " 14 " 16	....Silurian Grit, sub-angular.
54		19 " 17 " 11	....Andesitic Agglomerate, well rounded, polished.
55		22 " 13 " 6	....Diorite.
56		16 " 14 " 9	....Andesite, striated axially.
57		23 " 14 " 10	....Andesitic Agglomerate, rounded.
58		23 " 18 " 11	....Dalbeattie Granite, rounded and well polished.
59		22 " 23 " 16	....Andesite, rounded.
60		20 " 16 " 11	....Andesite.
61		27 " 17 " 13	....Criffel Granite.

62	Between Fulwood and Otterspool.	32 by 22 by 10....	Andesite, pear-shaped, striated axially.
63		45 ,, 32 ,, ?	Andesite, pear-shaped, sub-angular.
64		59 ,, 36 ,, 36....	Andesite (?) striated axially and polished.
65	40 yds. E. of stream Otterspool Mill.	96 ,, 50 ,, 16+..	Andesite, flat surface, partially buried in mud, axis N. and S., polished and grooved axially.
66	Embankment near Mersey Road	45 ,, 39 ,, 24....	Limestone with Silurian Corals.
67		36 ,, 27 ,, 12....	Eskdale Granite, tabular.
68		26 ,, 20 ,, 11....	Silurian Grit, pear-shaped, striated obliquely.
69		35 ,, 25 ,, 19....	Basalt, well scratched.
70		34 ,, 36 ,, 31....	Diorite, spheroidal.
71		26 ,, 21 ,, 9+..	Andesite.
72		27 ,, 21 ,, 12+..	Dalbeattie Granite.
73		27 ,, 24 ,, 12+..	Andesitic Breccia.
74		27 ,, 24 ,, 9+..	Diabase.
75		28 ,, 22 ,, 9+..	Andesite.
76	Between Embankment and Riversdale Road.	31 ,, 24 ,, 16....	Yewdale Breccia, polished and deep wide grooves.
77		27 ,, 24 ,, 14....	Criffel Granite, pear-shaped.
78		41 ,, 33 ,, 22....	Dalbeattie Granite.
79		22 ,, 21 ,, 18....	Ash purple, polished.
80		40 ,, 31 ,, 11+..	Criffel Granite.
81		41 ,, 32 ,, 16....	Scotch Granite, tabular, rounded.
82		44 ,, 34 ,, 19....	Fine grained Granite, tabular, striated axially.
83		32 ,, 21 ,, 23....	Granite grey, with gneissic structure, rounded and smooth.
84		26 ,, 20 ,, 16....	Scotch Granite, sub-angular.
85		27 ,, 16 ,, 12....	Diabase (?)
86	Corner of Foundry, Garston.	40 ,, 32 ,, 18....	Granite, well rounded.
87	Shore at Garston, near Battery.	38 ,, 37 ,, 17....	Andesite, axis N. and S., polished at top and striated axially; striæ from N.
88		29 ,, 22 ,, 14....	Granite axis N. and S., pear-shaped, blunt end N., polished.
89		24 ,, 15 ,, 9....	Andesite, rounded, polished.

90	Shore at Garston, near Battery.	42 by 13 by 14	Dalbeattie Granite, fractured.
91		19 ,, 17 ,, 9	Dalbeattie Granite, rounded.
92		47 ,, 42 ,, 16	Criffel Granite, embedded in Boulder Clay cliff, in situ, grooves N. and S., axis N. and S.
93		48 ,, 34 ,, 22	Andesite, axis N. and S., striated from N. axially.
94		38 ,, 24 ,, 16	Dalbeattie, polished on one side, fractured.
95	Group near Targets	26 ,, 24 ,, 12	Scotch Granite, axis N. & S,
96		39 ,, 37 ,, 25	Scotch Granite, axis N. and S. striæ from N.
97		29 ,, 17 ,, 17	Andesite, axis N. and S.
98		30 ,, 28 ,, 9	Dalbeattie Granite, polished and grooved from N., axis N. and S.
99		23 ,, 20 ,, 12	Andesite, axis N. and S. striæ axial.
100		28 ,, 16 ,, 14	Limestone, axis E. and W., striated, N. and S.
101		28 ,, 17 ,, 17	Granite, axis N. and S., striated axially.
102		34 ,, 28 ,, 12	Andesite, evidently moved.
103	Beyond Targets	45 ,, 37 ,, 20	Diabase.
104	Oglet Point	27 ,, 12 ,, 14	Silurian Grit, striæ axial, axis N. and S.
105		23 ,, 20 ,, 15	Criffel Granite, rounded.
106		23 ,, 21 ,, 12	Diorite.
107		17 ,, 14 ,, 8	Criffel Granite.
108		22 ,, 9 ,, 10	Andesitic Agglomerate, pear-shaped, blunt end N., striated axially.
109		20 ,, 16 ,, 10	Dalbeattie Granite.
110		30 ,, 17 ,, 24	Scotch Granite.
111		43 ,, 32 ,, 21	Andesite, striated.
112	Crow's Nest to Hale Head.	21 ,, 18 ,, 12	Dalbeattie Granite, striated axially, axis N. and S.
113		35 ,, 28 ,, 18	Andesite, pear-shaped, blunt end S., axis and striations N. and S.
114		34 ,, 24 ,, 18	Andesite, rounded, striæ and axis N. and S.
115		29 ,, 21 ,, 20	Andesite, rounded and polished, striæ and axis N. and S.

E

116	Crow's Nest to Hale Head.	25 by 19 by 12....	Andesite, sub-angular, striæ and axis N. and S.
117		28 „ 20 „ 18....	Scotch Granite, rounded, striæ and axis, N. and S.
118		23 „ 22 „ 18....	Scotch Granite, polished, axis N. and S.
119		26 „ 21 „ 12....	Scotch Granite, rounded and polished, axis N. E. and S.W.
120		29 „ 18 „ 18....	Andesite, striæ axial, axis N.W. to S.E.
121		21 „ 21 „ 6....	Scotch Granite, triangular, striæ and axis, N. & S.
122		28 „ 25 „ 12....	Scotch Granite, axis E. & W.
123		28 „ 18 „ 18....	Scotch Granite, triangular, and polished, E. & W.
124		22 „ 18 „ 18....	Scotch Granite, striæ transverse, axis N. and S.
125		34 „ 25 „ 20....	Andesite, striæ and axis N. and S.
126		64 „ 46 „ 36....	Scotch Granite, rounded and polished.
127		40 „ 36 „ 40....	Scotch Granite, polished, axis N.E. and S.W.
128		24 „ 22 „ 20....	Andesite, striæ transverse, axis S.S.W. and N.N.E.
129		22 „ 22 „ 12....	Andesite, hexagonal, polished and striated, axis N. & S.
130		32 „ 26 „ 20....	Andesite, striæ and axis, N.W. to S.E.
131		Diameter 34in.....	Scotch Granite, circular, polished.
132		38 „ 31 „ 24....	Scotch Granite, axis E. & W.
133		30 „ 22 „ 24....	Scotch Granite, axis N.W. and S.E.
134		32 „ 24 „ 16....	Andesite, striæ and axis N.W. to S.E.
135		28 „ 20 „ 20....	Andesite, striæ and axis N.W. to S.E.
136	Opposite Hale Lighthouse.	84 „ 30 „ 42....	Andesite.

NOTES ON THE DEVON COAST SECTION, FROM EXMOUTH TO SIDMOUTH.

By E. Dickson, F.G.S.

The rocks met with in this Section are, commencing at Exmouth (where those lowest in the series occur), and keeping to the Divisions made by Mr. Ussher:

(1) Breccias;
(2) Marls and Sandstones (Lower Marls and Sandstones);
(3) Pebble-beds;
(4) Sandstones with Conglomerate layers (Upper Sandstones)
(5) Marls (Upper Marls).

I. Breccia Beds.

These beds, which dip at a comparatively high angle, extend from Exmouth to Torquay, and differ considerably in character and composition. At Exmouth the uppermost beds consist of "deep red indurated Sandstone, brecciated with angular grit fragments of uniform size," while at Teignmouth and near Torquay the included fragments are volcanic, often slightly rounded, and vary in size "from that of a pea to that of a man's head." Whether these beds should be classed as Permian or Triassic is still an open question, but taking into account the difference in dip and lithological character between these breccias and the Marls and Sandstones occurring to the eastwards, there does seem to be sufficient evidence for separating these Breccias from the Marls and Sandstones, and considering the former as of Permian age. The beds now being

described terminate about a mile from the Point, where a fault throws down the beds of Marl and Sandstone to be next described.

II. Marls and Sandstones.

These beds extend from the fault last mentioned to a point about 550 yards W. of Budleigh (where they run out beneath the Pebble-beds), and are throughout cut up by very numerous faults. The Sandstone just east of the fault which throws it down is a red fine textured Sandstone without pebbles, with hard beds separated by others of soft Sandstone. The main mass of Marls extend from where they crop out beneath the Pebble-beds to a point about a mile beyond where the Pebble-beds die out. They are of a deep terra cotta colour, with whitish greenish layers about 4in. thick, and occasional harder layers averaging about 10in. thick. Dr. Irving refers to the similarity in colour and composition between these and the Permian Marls of Nottingham, and from this and the abrupt change between these Marls and the overlying Pebble-beds, and the evidence of erosion before the deposition of the latter, judges these Marls to be of Permian age.

III. Pebble-beds.

Overlying the Marls come the well-known Pebble-beds. These beds commence on the east, at a point about 100 yards west of a path opposite the Rolle Arms Hotel, Budleigh, leading to the beach, and extend for about 450 yards west of the village (during which distance they form the "substratum of the beach.")

At this point the Lower Marls come in and the Pebble-beds begin to ascend; they continue for about 1 or 1¼ miles further to the west, where they die out. At the easterly point of commencement, they are overlaid conformably by about 70 feet of overlying Sandstone, which latter dies out about 400 yards west from where the beds of Lower Marls come in. The Pebble-beds at their greatest thickness are about 100 feet, the average thickness being about 60 to 70 feet. They gradually increase in height westwards, the height of the cliffs where the Marls come in being about 200 feet.

The appearance of the cliff, as seen from below, is certainly very striking, and bears a strong resemblance to some of the sections in the Triassic Conglomerate at Cannock Chase, and very unlike any section in the Pebble-beds of Lancashire. Intercalated with the pebbles are beds of rock sand or soft sandstone, the latter often with harder layers running at right angles through them. The beds as a whole afford several excellent examples of strong current bedding. The pebbles themselves are imbedded in a loose reddish sand, and are of all sizes and shapes—the majority of the pebbles, however, being ellipsoidal and about 8in. in diameter—many being also spherical and discoidal, pebbles of different sizes, occurring at different elevations. The largest one that I measured was an ellipsoidal pebble, 15in. long and 9in. in diameter. The pebbles were nearly all of purplish quartzite, and of the pebbles projecting from the cliff fully 5 per cent. were split at right angles to their axes, and apparently lay with their longer axes parallel to the dip, which was only about 4° to the N.E. There were numerous small faults at varying distances and heights. Further north the pebbles change to grit and quartz (the quartzite being

replaced by material of local origin) and become smaller, until at Thorn St. Margaret, only twenty miles in a straight line from the coast, the beds pass into Conglomerate of local origin (Ussher). As is well known, traces of fossils are occasionally found in the quartzite pebbles, the best public collection of which is to be found I think in the Exeter Museum. Mr. Salter's opinion of these fossils is that they are Norman types of the May Hill Sandstone (Silurian), while Mr. Davidson on the contrary says, that "with very few exceptions the Brachiopoda are of Devonian age." Mr. Ussher, however, rightly points out that this latter remark applies to the Brachiopoda only, and that of the sixteen conchiferæ examined all were Silurian. The presence of traces of fossils in the pebbles is of interest, as being likely to throw light on the very difficult question as to the origin of these pebbles. Of one thing there seems to be no doubt, namely, that the source of origin must have been at some distance from their present position, and that the pebbles have probably been carried by currents from the south. Some years ago it was suggested by Mr. Linford (a Devonshire geologist), that the pebbles were derived from a Pre-Triassic extension of the Silurian Rocks of Calvados and La Mancha (in Normandy) into the site of what is now the English Channel. I have compared specimens from these localities with pebbles from Budleigh, and certainly the resemblance is very striking. There is also a strong resemblance between pebbles from Budleigh and those from the Cannock Chase district, although in the case of pebbles from the latter district, the admixture of pebbles of rock, other than quartzite, is more common, and fossiliferous pebbles are much rarer. Mr. Etheridge has suggested that these Budleigh Pebbles might have come from Gorran Haven,

in Cornwall, but it is quite possible that the pebbles have come from more than one locality.

With regard to the age of these Pebble-beds it is only possible to make a conjecture. Probably Dr. Irving is right in his view that they are "Middle Bunter." If this be so, and the Marls below are Permian, then the Lower Bunter is absent altogther from the South Devon area.

Upper Sandstones (Ussher).

Overlying conformably these Pebble-beds are beds of red Sandstone with layers of Clay or Marl, which extend from a point about 500 yards West of Budleigh to the Chit Rock, East of Sidmouth. These rocks are of interest as it was in them that the Hyperodapedon was found at Otterton Point, by Mr. Whittaker, in 1868, and the remains of Labyrinthodon and other reptiles by Dr. Carter, Mr. Lavis, and Mr. Metcalfe, subsequently. At Otterton Point intercalated with the Sandstone are two or three beds of Conglomerate or Breccia containing angular or slightly sub-angular fragments of quartz granite, slate, &c., and it was in one of these lowest hard hard layers that Mr. Whittaker found the jaw bone of the Hyperodapedon. At Ladram Bay (about half way between Budleigh and Sidmouth) the sea has scooped out of these Sandstones a small picturesque bay leaving pillars of rock, through one of which it has bored a passage for itself. The lower part of the cliff consists of hard concretionary bands, the upper part being of softer Sandstones, which are thrown down by a fault at Ladram Bay to a level with the Conglomerate beds beneath.

The following is a section of High Peak Hill, near Sidmouth:—

Greensand	....	113 feet.
Upper Marls	....	200
Upper Sandstones	....	200 „
	Total......	513 feet.

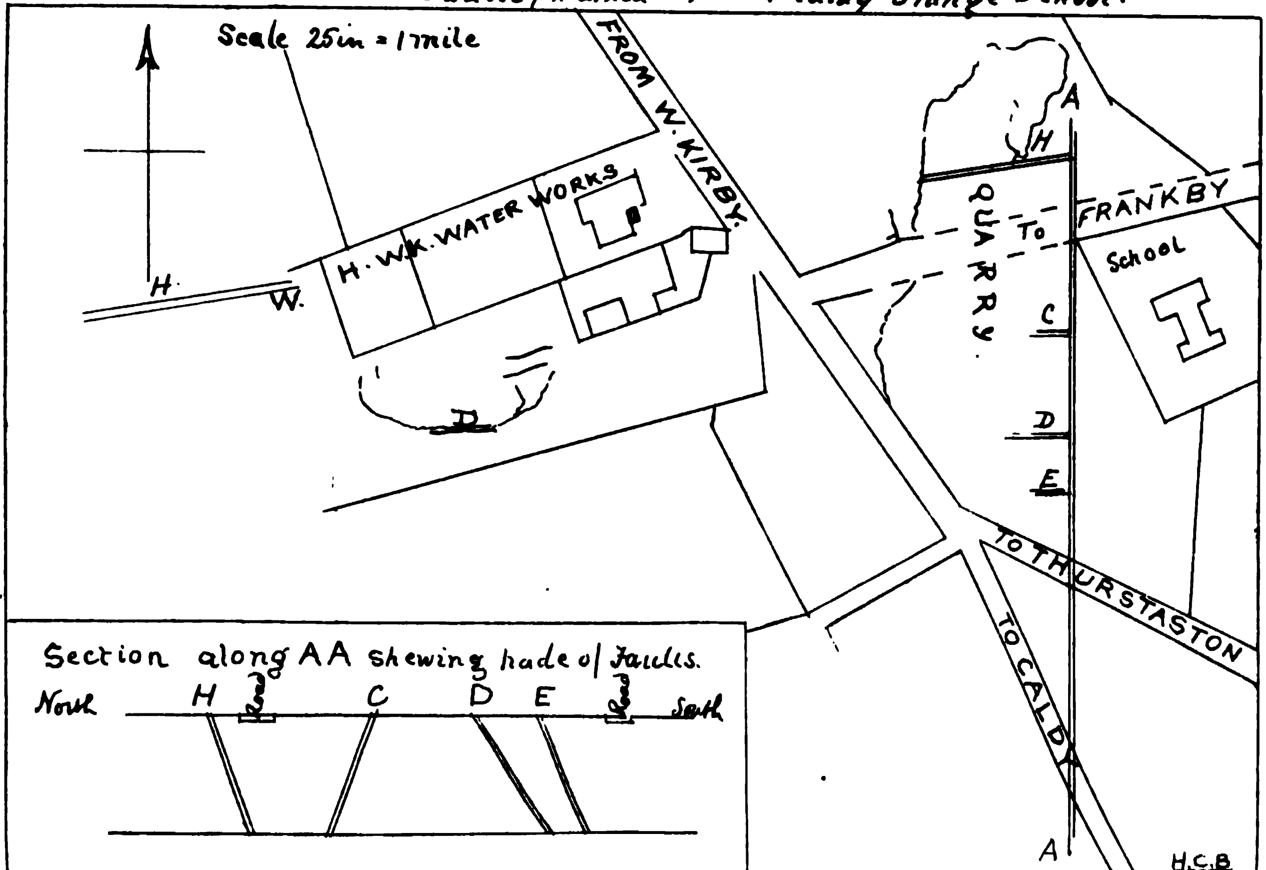
The remains found by Lavis and others were supposed by them to come from the upper 10 feet layer of the Sandstone which appears at the surface a little to the West of High Peak Hill. The Sandstones here underlie the Marl, and in their upper part resemble the lower beds of Marl. The Sandstone (which dips to the East) is hard, rather coarse in texture, light in colour, ripple marked, and contains pseudomorphs of rock salt. The bones were found in blocks which had fallen from the cliff to the shore and formed a small talus in the cove known as the "Picket Rock Cove." As the cliffs here are vertical and their base can only be approached at low-tide, it is very difficult to get at that part of the cliff from which the blocks have probably fallen. Nearer to Sidmouth, the Sandstones under Peak Hill disappear, and then reappear with a Westerly dip. They appear for the last time at the Chit Rock just West of Sidmouth (where a fault with a throw of about 200 feet throws down the upper Red Marls), and for a short distance on the Easterly side of the River Sid.

Upper Marls.

These beds, the last to describe, overlie the Sandstones, and are well seen under High Peak Hill, near Sidmouth, where they reach a thickness of 200 feet. The marls at High Peak Hill are stiff reddish marls, with bluish bands in their upper parts, and intersected

Plate IX

Plan of Faults (marked =) near Caldy Grange School.



to illustrate paper by Messrs Lomas & Beasley.

by gypseous bands, the lower parts passing into sandstone or rock sand. Running through the marl, and occupying a space of about 30 or 40 feet of the cliff, are parallel bands of hollow nodules lined with crystals of carbonate of lime. Below this again, is a band which might be called the Celestine Band, consisting of a line of hollow nodules, with crystals of carbonate of lime, on which celestine has formed; 8 or 10 feet below this band is a band, called by Mr. Hutchinson, the discoverer, "The Plant Band," at the base of the Marls, and which runs out a little to the east of Peak Hill. The plants are figured and described by Mr. Hutchinson (Trans. Dev. Assoc., vol. xi., 383). Ten feet below this plant band in the Sandstones are white bands of varying thickness, and in Mr. Hutchinson's opinion the Saurian band strikes down to the beach under Windygate, and is much lower than where Mr. Lavis is inclined to put it.

ON SOME EAST AND WEST FAULTS AT CALDY GRANGE.

By H. C. Beasley and J. Lomas.

In January, 1887, Mr. O. W. Jeffs described before this Society* a very fine flank exposure of a fault occurring in a quarry near Caldy Grange Grammar School.

It is one of the N. and S. faults which prevail in our district, and throws down the Keuper basement beds against the Bunter.

He also described three East and West faults with varying hades, abutting on the main fault.

* Proc. L'pool Geo. Soc., Vol. v., p. 247, pl. iii.

Since then the quarry has been extended northwards beyond the road leading to Grange, and about 60 yards N. of the road, another E. and W. fault has been exposed. Following the lettering in Mr. Jeffs' plan, we will call this H.

The hade is 15° S. (the inclination is measured from the vertical).

It is continued westwards in a slightly sinuous line having a general direction of 15° S. of W. We have not traced it eastwards from the N. and S. fault, but there are a few insignificant cracks, in a line with H, seen near the footpath which runs parallel with the great fault, and a few yards eastwards of it.

We have proved H to be identical with a fault exposed in a little quarry just outside the boundary wall on the west side of the waterworks, and the fault D is also exposed on the south side of the quarry, south of the waterworks.

In the little quarry W. of the waterworks the fault H. is seen to have a beautifully polished and slickensided surface. The base of the Keuper is exposed in the cutting, and the lines of bedding are continued across the fault without the slightest throw.

Further west the fault is wholly in the Bunter. It is about 6 feet wide, and the fault rock is split up into a number of vertical pieces with slickensided faces from 1 to 6 inches apart. The hard fault rock has resisted the forces of denudation better than the surrounding Bunter, and stands out as a ridge at right angles to the axis of the hill.

From the high degree of polishing and the amount of induration which the faces of the E. and W. faults

show, it is evident that great movements have taken place along the line of those faults.

We are inclined to believe that they are due to differential movements in the Keuper during the time the great N. and S. fault was in process of formation.

It does not necessarily follow that the Keuper would fall at the same rate or at the same time along the whole flank of the fault.

If the slip occurred up to a certain point and the rock fractured there, and afterwards the portion beyond that slipped, the two faces would slickenside each other, and in some cases a throw equal to that of the main fault would leave little or no residual throw in the transverse faults.

We venture to put forward such a theory to account for the facts put before you, and in order to make the matter clearer we have prepared a working model of the faults.

The portion between H and C forms a wedge-shaped mass which thins out downwards, and the two faults would meet at a vertical depth of about 150 feet. The mass also thins out westwards, and C would probably strike H at the East end of the ridge of fault rock before mentioned, 500 feet from the N. and S. fault.

The portion between C and D is also wedge-shaped, but thins out upwards.

D E too is wedge-shaped, and like H C thins out downwards. The faults D and E would meet at a depth of about 370 feet along E.

The piece C D bears a great resemblance to the key-stone of an arch inverted, and that was probably the portion which first fell.

The pieces on each side would then be left unsupported, and they falling, would produce the slickensided surfaces described.

ON SOME POTHOLES ON THE SHORE NEAR DINGLE POINT.

By J. Lomas, Assoc. R.C.S.

Special Lecturer on Geology, University College, Liverpool.

The shore south of Liverpool, between the Herculaneum Dock and Dingle Point, consists of a low platform of rock about 500 feet wide. It is bounded inland by cliffs of sandstone 30 or 40 feet high, and at low water mark it suddenly descends about 30 feet. The platform has very little slope riverwards, and the surface is irregular in places, owing to beds of harder rock. Several faults occur in this area, and they can be traced by the ridges of fault rock, which, being harder than the surrounding Upper Bunter Sandstone, have better resisted the forces of denudation.

No better examples of false bedding could possibly be found than these sandstones exhibit: the strike differs every few yards. Beautiful contortions are also seen in the cliff sections along with the false bedding, and the faces of the cliffs are worn into most fantastic shapes.

At low water the platform is usually to a large extent covered with a layer of silt; the covered areas change day by day, and after a storm the whole shore may be almost free from mud.

The potholes are irregularly distributed over the platform, and they are also found S. of the Point nearly as far as Knott's Hole.

On a recent visit I noted 20 groups, and fixed their positions on a plan of the shore.

They are of varying shapes and sizes. Some are circular, others oval; many are slipper-shaped—*i.e.*, elongated and contracted a little at the sides. At the point of contraction there is invariably a transverse ridge shallower than the heel and toe, and corresponding to the arch of the slipper. Several annular specimens were found, consisting of a circular excavated ring containing the pebbles, surrounding a central pillar.

A good example of this variety can be seen on the shore about 250 yards S. of the Herculaneum Dock, and about 50 yards from the wall. It is almost perfectly circular; the total diameter is 25 inches, the central core is 12 inches, thus leaving a ring which is 6½ inches wide and 3 inches deep.

The circular potholes are the most numerous. Among them one has a diameter of 5 feet and is 2 feet deep, and another has a diameter of 3 feet and a depth of 2 feet.

In the groups containing elongated examples the longer axes are always parallel to the strike of the beds; so, while parallel to other members of the group, they may differ in direction from a group only a few yards away. The oval and slipper potholes range in size up to 9 feet in their longest diameter, and 1 foot 9 inches deep.

Some of the prettiest potholes occur at the bases of the little cliffs which abound over the area, and these have not only been cut vertically but also horizontally, thus undercutting the vertical face of the cliff. Examples of this kind are found 2 feet in diameter and 2 feet 6 inches deep.

The potholes have undoubtedly been produced by the scour of stones moved by the strong currents which sweep over the platform. The current strikes

the shore very acutely at this point and is then deflected back again, and in the little bay a little to the S. of the flagstaff a constant swirl is noticed; and I have no doubt if this bay were at any time free from water we should see a huge pothole at the bottom. I am at a loss to account for the annular variety, unless the central portion has been protected by a boulder, and the ring has been formed by the stones sweeping round it. The shore S. of Dingle Point is thickly strewed with large boulders, but to the N. scarcely one is to be seen; they have probably been removed.

The slipper-shaped examples have probably resulted from the union of two neighbouring potholes, and the bridge is the intermediate piece not yet removed. One part of the slipper is often deeper than the other.

We must not lose sight of the fact that artificial holes have been made in various parts of the shore; but these are easily recognised, and I have not included any cases which seemed in the least to be doubtful.

THE TRIAS OF CANNOCK CHASE,

BY T. MELLARD READE, F.G.S., &c.

DURING last Easter I made arrangements with Mr. Henry C. Beasley and Mr. Edmund Dickson to visit Cannock Chase, with the object principally of examining the Triassic rocks in that neighbourhood. We had an exceedingly pleasant time, and making Rugeley our headquarters, under the experienced guidance of Mr. William Fairley, F.G.S., agent to the Marquis of

Anglesey, managed to see about as much as was possible in the time. I take the opportunity here of thanking Mr. Fairley for the unrestricted way in which he placed his time and local geological knowledge at our disposal.

The district called Cannock Chase has not, that I could find out, very defined boundaries. Anciently it was a forest and hunting ground of the Mercian and Norman kings, extending to Bednal, Lichfield and the Trent, with an area of about 25,000 acres. It was long covered with wood, but is now largely moorland. Much of the Chase is hilly, its highest point, Castle Hill, being crowned with a British double-trenched camp of 8 or 10 acres.

Geologically Cannock Chase does not seem to be much known. I had considerable difficulty in getting information of even the preliminary character necessary for our purposes. Eventually I succeeded in getting a copy of the 2nd Edition of Juke's Memoir on the South Staffordshire Coal-Field, which appears to embody most that is known. This absence of information is rather strange, as from within a couple of miles of Rugeley to as far south as Dudley, the country is a successive series of coal mines. It is evident also from what we learned from Mr. Fairley that much more is known of the strata now than in Juke's time, thanks to the energetic coal mining.

The northern end of the island, so to speak, of Coal-measure rocks, is the portion we principally examined.

The Marquis of Anglesey's demesne of Beaudesert is situated on the highest ground, which is mostly Coal-measures, but against this old land, to the north-west, lie the Conglomerate beds of the Trias, which have been

pierced in several places in sinking for coal. The eastern boundary appears to be formed by a fault, which lets down younger members of the Trias which occupy the ground as far as and beyond Lichfield.

The Triassic Conglomerate is, to one used to the sandstones of Lancashire and Cheshire, a very remarkable deposit. What are called the Pebble-beds in these counties are, as is well known to the members of the Liverpool Geological Society, as a rule, simply sandstones with a few quartzite, quartz and other pebbles scattered through them. They are largely used for building stone in the neighbourhood of Liverpool. Some few sections are to be seen, such as at Burton Point on the estuary of the Dee, and at Holt, on the river Dee above Chester, where several of the beds are of a more conglomeratic nature, but practically they are still sandstones with beds of pebbles in them.

The Cannock Chase Conglomerate in the typical sections I am about to describe, is composed almost wholly of pebbles and boulders, the majority being of quartzite, sandstones and grits, but a large proportion being also of other rocks including silurian, carboniferous, and igneous. These pebbles and boulders are greatly rounded, showing signs of a vast amount of wear and attrition.

So closely packed are they that impressions of one stone are found in that of another; some of the boulders being indented by pebbles so small as to be classed only as gravel. The interspaces of the stones are filled with crumbly sandstone, or even sand, forming a general matrix, but some of the bands are harder, calcareous, and more indurated. The thickness of these Conglomerate beds, as proved in the various colliery

sinkings, is stated by Mr. Fairley to be about 200 feet, but further details will be given.*

Another peculiarity of these Conglomerates, or gravel beds as they are locally termed, is the comparatively high level at which they are found, and the fact that they rest directly upon the Coal-measure rocks. They occur as high as 650 feet above the sea.

I will now proceed to describe some of the sections.

SECTION AT MOORES GORSE.

About 2½ miles S.W. of Rugeley, on the Walsall and Cannock Railway, is a cutting through the Conglomerates which admirably exhibits their character. The section is on the west side of the railway, and has been much extended by excavating for ballast. The height of the highest part above rail level is about 75 feet. The strata are composed of a mass of pebbles and small boulders imbedded in loose sand. The pebbles are of a great variety of rocks, quartzite and sandstones preponderating. Practically the pebbles are like what we find in our Pebble-beds, and the quartzites are of the same varieties, but they do not so overwhelmingly preponderate over the other rocks as with us.

In places there is a larger quantity of sand and fewer pebbles, and the rock becomes a coarse sandstone which juts out from the face of the excavation. The pebbles lie very regularly in horizontal beds, and so far as I could see current-bedding was absent. There are a good many

* Jukes says ("Memoirs of the South Staffordshire Coalfield," 2nd Edit., p. 5) "The Pebble or Conglomerate beds lie below the Upper Red and Mottled Sandstone. They vary in thickness from 300 to 500 feet, and in our district are probably thickest south of the Lickey Hills, and in Cannock Chase, north of Cannock. They range from a fault near Blackwell Station, south of the Lickey, to Hagley, lying here directly on the Permian strata, without the intervention of the Lower Red and Mottled Sandstone."

pebbles of igneous rocks, and as a rule these are much decomposed. The surface in some places for considerable depths has been redistributed as drift, but the Conglomerate is often of so loose a character that it is in many cases impossible to say where the one ends and the other begins, or whether a particular bed is Conglomerate or drift.

See section Fig. 1.

The Conglomerate reaches the height of 600 feet above the sea level on the hills, is deeply cut into by the streams, and must have contributed a great many pebbles to the River Trent. Not far from this section is the pumping station of the South Staffordshire Waterworks, the well 80 feet deep being wholly in the Conglomerate. I understand that there is a good supply of water.

Fair Oak Pit, about three-quarters of a mile to the north-west, was sunk through about 200 feet of the Conglomerate or gravel beds as they are called. Mr. Fairley took us to the shaft, and on the heap alongside pointed out some very hard calcareous pieces of rock apparently containing copper (green carbonate). In places the Conglomerates are 250 feet thick as proved by pit shafts, and according to Mr. Fairley lie in bays washed out of the Coal-measures. The Section Fig. 3 shows the relation of the Conglomerate to the Coal-measures, according to a sketch section Mr. Fairley made on the ground for us.

The following are some of the localities where the "gravel beds" or Conglomerates have been pierced.

Bore-hole about 1¼ mile west of Fair Oak Pit. 150 feet to Coal-measures.

Bore-hole, Wolseley Park, about $2\frac{1}{4}$ miles west of the town of Rugeley. 170 feet to Coal measures.

Cannock and Rugeley Colliery, Hednesford, about two miles north-west of Cannock. 180 feet to Coal-measures.

At Beaudesert Park, at 650 feet above sea level, the Section Fig. 5 is to be seen. According to the Survey this is in the Pebble-beds, but it looks much like Keuper Sandstone.

Not far from this, at a level of about 700 feet above the sea, there is a quarry in the Keuper Sandstone. The usual type of rock without pebbles.

Artificial faults are observable in many places on the hills, caused by the letting down of the strata by the mines. The reservoir of the South Staffordshire Water-works was let down half-a-dozen times, but, strange to say, it did not flood the mines.

The "gravel beds" are, as shown in the well of the South Staffordshire Waterworks, water-bearing; but if in sinking a pit shaft the water is "tubbed out" in the gravel beds, the mines below are, according to Mr. Fairley, remarkably dry.

Gravel Pit, Milford.

A gravel pit near Milford, on the left-hand side of the road to Satnall Hills, yielded a brown sandstone pebble, considered by Dr. Chas. Callaway, to whom it was submitted, to be Upper Llandovery from west of the Severn, containing *Leptocœlia* (*Atrypa*) *hemisphærica*, *Pentamerus*, *Orthis Elegantula*, *Favosites fibrosus*, and other fragments detailed in Appendix (No. 6). A somewhat similar, but more friable fossiliferous pebble, was found by Mr. Beasley.

Satnall Gravel Pits.

In the Satnall Hills, not far from Milford Station, on the road to Rugeley, very fine sections of the Conglomerate beds are to be seen.

The stones are much larger than the average at Moores Gorse already described. The largest boulder I measured was of quartzite, 14 in. by 8 in. and splendidly rounded, but there were many others approaching this size. The sketch, Fig. 4, represents its mode of occurrence and position in the excavation.

The excavations stand quite vertical, although the sandstone or sand matrix is generally of so loose and crumbly a nature.

The thin beds shown in the Sections Nos. 1 and 2 are indurated beds of sand, or they may be called sandstone. There is another gravel pit further on than No. 2, of a similar character.

Gravel Pit No. 1, on the left-hand side of the road to Rugeley, is the first seen when proceeding from Milford Station. It is a splendid section of the Conglomerates, built up nearly altogether of pebbles and boulders. It is largely made up of boulders, averaging 6 inches in diameter, many being 9 inches, and one already described, 14 in. by 8 in. These boulders and pebbles are quite pitted with the depressions made at the contact with small gravel which often is cemented firmly into the saucer like holes. The stones have quite a singular pock-marked appearance. The beds of sandstone thicken, and thin out, and often die out altogether. The stones are at all angles, but generally approach the horizontal. The fault shewn in section has a throw of a few feet, and the stones in it are placed end on.

No. 2 Gravel Pit is remarkable as containing a bed at where the stones are arranged in the oblique manner known as current-bedding, the only example I noticed. The stone and the general colour of the gravel is grey, having a slight tinge of green in it. We found in this section silurians with fossils, and some much decayed fossiliferous and carboniferous limestone. The quartzite and sandstone boulders are "pitted" as described elsewhere, and also the limestone.

Sections of the Conglomerate on a smaller scale are to be seen also near Wolseley Bridge, on the Trent. Near to this is a sand and gravel pit, evidently in the drift; it may be a glacio-fluviatile deposit of the Trent, composed of the materials of the older Triassic gravels.

At Stile Cop, nearly two miles south of Rugeley, a good section on a small scale of the Conglomerate is to be seen, and I got some excellent examples of the "pitted" pebbles and boulders from here. Mr. Beasley found a light brown sandstone pebble, considered by Dr. Callaway to be Ordovician from the west of the Severn area, and containing *Strophomena rhomboidalis*. The upper part appears to be re-arranged as drift, but where one begins and the other ends we find it impossible to say.

At Littleworth, Hednesford, is to be seen a yellow current-bedded rock so loosely built up as to be used for sand. It is about 600 feet above sea level. Intercalated irregularly in it is a bed of pebbles. The materials are local, and evidently derived from the Coal-measures.

This sandstone is interesting, partaking as it does, so much of the character and colour of the Coal-measure sandstones, and containing many coarse carboniferous sandstone pebbles as well as the usual quartzite. It

seems that here at all events the local conditions have influenced the character of the deposit, which is uncommon in the Triassic Rocks.

The Littleworth Brick and Tile Works Company have excavated a large pit in marls that, according to Jukes, are in the upper Coal-measures. The upper bed is red marl, with hard irregular nodular bands intercalated therein. The lower bed is of red and grey variegated marls, and from this the blue Staffordshire bricks are made. The marl is like the Sweeney Hall terra-cotta clay near Oswestry, excepting that the latter contains some very yellow beds. There are, however, no Permians shown on the Survey Map near Littleworth, and it was impossible for us to work out the stratigraphy in the time at our disposal.

One of the walks we took was from Lichfield to Rugeley. I cannot help remarking on the unique beauty of the Cathedral. I had seen it once before, but on this occasion the trees being leafless, much more could be seen of its proportions. It was a sunny day, and a blue cloudless sky formed a fitting background to the noble pile. The colour of the stone, of a rosier and clearer shade than is usual in the Trias, shading off into and dappled with grey in places, has much to do with the pleasing effect of the *ensemble*. This, together with the tracery of stems and branches through which it was seen, the delightful grouping of the western and central towers and spires, and the elaborate ornamentation of the western front, one mass of canopied figures and tracery, made a picture that will not readily die from the memory.

The stone used is, I believe, from the Keuper of the neighbourhood. The cathedral has been entirely

restored on the west front by the late Sir Gilbert Scott, and very well done it is. Canon Lonsdale informed me on a previous occasion that the stone used in the restorations had come from quarries on Cannock Chase, and is of a more durable nature than the ancient stone. We had not time to enquire and verify this statement, if a Canon's statement requires verifying, but of the beauty of the stone there can be no question.

In Longdon Church, about half-way between Lichfield and Rugeley, an interesting Norman Chancel Arch with lozenge ornamentation is to be seen. The Tower and South Transept are "perpendicular," the whole being built of the red Triassic Sandstone.

At Brereton Hill, is to be seen a coarse yellow grit, with quartzite pebbles. According to the Survey, this is the Conglomerate or Middle Bunter.

Keuper Sandstone.

In the railway cutting south of Rugeley Station, at the Junction of the branch to Hednesford and Walsall, sections of the Keuper sandstone may be seen. A bed of hard grey sandstone (Keuper) rests upon an eroded surface of soft yellow sandstone. This capping of Keuper sandstone is seen on both sides of the railway. Whether the underlying soft yellow rock is Keuper or Upper Bunter we could not determine.

At Longdon Upper End, about 1½ miles south of Stile Cop, is an exposure of rock which I took to be Keuper, but the Survey gives it as Conglomerate beds (Bunter).

Abbots Bromley.

Being within reach of the Lias of Abbots Bromley, we were anxious to compare it with our recollections of

the outlier of Salopian Lias at Prees. We devoted a day to this work, driving to Abbots Bromley and walking over Bagots Park. According to the Survey, the Lias is an outlier lying upon the Keuper Marls. It is, however, very difficult to decipher and to find out the junction, as the country is superficially covered with drift and the waste of the rocks below, which are Lias and Trias, alike marly and soft. It is, however, in many cases possible to find out when one is on the Lias or the Trias by the nature of the soil. The Lias is a dark coloured grey marl, and after great searching we found it exposed in a little stream —a tributary of one of the coombs—at "The Cliff," where the ground is comparatively high. I believe we should have seen a much better section on the road to Uttoxeter if we had proceeded further. I should think the Rhætics ought to occur here, but probably it would require excavations to disclose them.

Bagots Park is full of splendid oaks in all stages of life and decay. Many, though still growing, are quite hollow—some even uprooted. There is a coating of drift all over the surface made up of washings of the Lias, mixed with usual Triassic pebbles.

In the village of Abbots Bromley there are some very good examples of half-timbered work. I noted the date on one of the beams in a building I sketched was 1619. It is rich work of a late period, but it may be earlier than this.

The church, built of Triassic Sandstone, has been lately restored. It is Geometric Gothic, but possesses a Classic tower of the dark ages of Art. Geologically speaking, the day was distinguished by what we did *not* see; but we enjoyed it thoroughly.

The "Green Rock" of Bentley.

Though this visit is not exactly in our programme of the Trias, I purpose recording what we saw here, as the rock possesses a good deal of physical interest.

The "Green Rock of Bentley" is part of an intrusive sheet of basalt, of which Rowley Regis is the best known example; it is the same rock as the well-known "Rowley Rag." This intrusive sheet lies under the "Thick Coal," and between the "Fireclay" and the "Bottom Coal" at Bentley. In other places it is found both over and under the "Thick Coal." At Rowley Regis it is under the "Thick Coal." The rock is found in places over an area of 45 square miles.

In the railway cutting between Cannock and Bloxwich the Silurian (Wenlock Shale) is seen (not shown in the Survey sheet). Between Bloxwich and Bentley we walked over a desolate country of worked-out mines, covered only with cinder heaps. We all thought it should be planted with trees, and brought back to a more natural condition.

The quarry at Bentley is about 3½ miles west by south of Bloxwich. It is worked for setts, kerbs, and macadam. The joint planes of the basalt are of a very deep ochre colour from decomposition. On a clean fracture the rock is a beautiful grey-green, and weathers black.

Fig. 6 is a sketch section showing the disturbance caused in the overlying coal shales.

Drift.

I have already stated that the drift over the Conglomerate beds is often almost undistinguishable from them, being composed of the same pebbles and sand; the

Conglomerates, on the other hand, being in many cases nothing but huge gravel beds.* The summit of Castle Hill, 800 feet above the sea, is covered with a slightly clayey drift containing the sand and small pebbles of the Trias, and in this the trenches of the British Camp are dug. In a brickfield on the Rugeley and Lichfield Road is a bed of clay without pebbles or stones, overlain by a clay with a few pebbles and stones, and then by a local drift and soil; the whole measuring 9 feet down to the rock. It is not of a very decided character in any way, but I look upon the upper clay at least as drift.

Near Milford Station there is a stratified yellow gravelly drift forming hillocks, covered by a superficial hill-wash. On the left-hand side of the road to Rugeley, before arriving at the Satnall Hills, there is a small gravel pit already mentioned, the gravels resting upon red sandstone, with patches of indurated Conglomerate lying thereon. The upper part of the gravels is probably drift. Near to Wolseley Bridge over the Trent, as already stated, are yellow laminated sands and gravels. They may be a deposit of the river in late glacial times. Between Stile Cop and the pumping station of the South Staffordshire waterworks, there is a bed of yellow drift sand, with a spring flowing from underneath. There is a drift of Conglomerate pebbles, sand, and a little clay over the highest hills, with the Coal-measures immediately underneath.

* "In examining a gravel pit for this purpose" (to discover if it is drift), "the first thing to look for is a chalk flint. True chalk flints with chalk fossils, may be in some places pretty abundantly found in the gravels of Staffordshire, as sometimes oolitic and liassic fossils." Often, however, there is nothing newer than the Coal-measures, but the sand of the drift is generally of a paler and yellower colour than in New Red, and the pebbles lie more confusedly.—Jukes' "Memoirs of South Staffordshire Coalfield," 2nd Edit., pp. 6-7.

In the town of Rugeley, Mr. Fairley showed us some erratic blocks which might have been altered ash or andesite from the Lake District. He informed us that similar but much larger blocks are found scattered over the higher ground of Cannock Chase far south.*

Old Iron Workings.

In the Old Park (Beaudesert) Mr. Fairley pointed out some scoria heaps. On one there was an oak tree growing 18 feet in circumference. From this fact the scoria is calculated to be about 400 years old. An analysis of the scoria yielded, we were told, 20 per cent. of iron. The smelting was done with wood, which will help to account for the destruction of some of the forest.

General Observations.

Comparing the Triassic Rocks of Cannock Chase with those we are familiar with in the neighbourhood of Liverpool, one is struck with the similarity of the Keuper Sandstones and the difference in the Conglomerate beds of the Bunter. If we compare the Bunter of Cannock Chase with that of the Vale of Clwyd† the difference is still more striking. The Bunter of the Vale of Clwyd rests directly on the carboniferous rocks practically without a pebble in it, so far as my observations extended.

The Conglomerates of Cannock Chase also rest directly on the carboniferous beds, and are, as herein described, one mass of pebbles and boulders.

---

* Blocks of granite and old trappean rocks, evidently belonging to the Great Northern Drift, are found in great abundance all along the western boundary of the coal-field, especially about Bushbury, and thence towards Cannock.—Jukes' Memoirs on the South Staffordshire Coalfield, Second Edit., p. 207.

† Trias of the Vale of Clwyd—Proc. L'pool Geol. Soc., Session 1890-91.

There are pretty strong conglomerate beds in the Bunter of Market Drayton, Shropshire, and there is a conglomerate of gravels of much smaller materials intercalated in the Bunter of Bridgenorth.

These Conglomerate beds seem, so far as my observations extend, to be developed more around the margins of the Trias than elsewhere, if not confined to this position. It is the same at Burton Point, and at Holt, in Cheshire.

The unconsolidated character of the Cannock Chase Conglomerates is another feature that strikes the observer from the North. What the relation of these Conglomerates is to the more homogeneous sandstones of the Bunter we had no means of ascertaining.

As I have already observed, some of the sandstones marked on the Survey map with the same colour and reference figure as the Conglomerates are lithologically more like Keuper sandstone than Bunter. There is little doubt that these finer sandstones as a rule overlie the Conglomerates.

Another noticeable feature is the height above the sea to which these Conglomerate beds reach where they lie on the Coal-measures. At Milford they are on a lower level, and it would be interesting to ascertain whether in this locality the Conglomerates are underlain by Triassic Sandstone. Only a well or boring could tell us this. It would also be interesting to discover whether the differences of level of the Conglomerates at say Fair Oak Colliery and at Satnall Hills are due to earth movements or original deposition. The remarkable horizontality of the Conglomerate beds points to the latter cause, though not by any means conclusively.

If we look at the general areal arrangement of the Trias, as exhibited in Greenhough's map, we find that it lies in connected basins of the Coal-measures, the central areas being largely occupied with the Keuper Marls, on which again we find in Shropshire, at Prees, and at Abbots Bromley and Christchurch, on Needwood in Staffordshire, outliers of the Lias.

The margins of the Triassic area are occupied with sandstones, sometimes Keuper, but more frequently Bunter, often lying on Permians. From this symmetrical arrangement one would be inclined to say, that the original deposition took place in basins or straits, which after earth movements have not succeeded in obliterating. If this be a valid induction we should naturally find that the Conglomerates would, as a rule, be found nearer to the shore margins. This is what I infer has happened, as I look upon the Conglomerates of Cannock Chase as shore deposits of the Triassic sea.

I am of opinion that such a mass of gravels and boulders, composed of extremely hard rocks, could not have been ground into their present rounded forms excepting by wave action. To say, as some do, that they have been derived from older Conglomerates, of which no one knows the whereabouts, is no answer to the difficulty, because the transport and accumulation of such an immense bank of boulder-gravels would require an agent quite as capable of rounding as of transporting them. Such a derivation is possible, but until we can point to an older Conglomerate of similar character, from which the younger one could be derived, it is unphilosophical to attempt to remove the difficulty in this manner.

The vexed question of the derivation of the quartzite I will not enter upon here, but speaking generally of the

physiography of the Trias I see no reason to depart from the views broached in my papers on the Physiography of the Lower Trias.*

There remains one interesting physical phenomenon to consider, and that is the pittings or depressions found in the hard quartzite, the sandstone, limestone, and other pebbles. These have been ascribed by some to lateral pressure, one stone being supposed to have been actually pressed into the other. I am quite satisfied that this is no explanation, for the greatest depressions, both in number and size, are on the flat surfaces of the pebbles, so that if pressure were the cause it has been vertical rather than lateral. It is in my opinion impossible for pressure alone to have caused the depressions, for the stones which have made the impress, often fine gravel, would have been crushed to powder before any depression could have been made in this way. It is evidently a case of contact-solution; the water flowing into and through the very porous beds will be retained by capillary attraction between the two surfaces in contact.

I believe that the surfaces of both pebbles at the point of contact are dissolved, but the under pebble the most; this will account for the saucer-like section the depressions usually assume. In one instance the depression is just as if the thumb had been drawn across butter.

The silica is also re-deposited on the surface of the depression, hence the smoothness of the surface and the fact that the skin of the depression, when a pebble is split across the indent, sometimes sticks out laterally in a shell-like form.

* Geological Magazine, dec: iii., vol. vi., pp. 549-558.

The pebbles are often cemented together by silica, so that in some cases broken pebbles are found in the depressions. That solution of the silica is taking place is shown by the conglomerate of sand and siliceous gravel sometimes adhering to the pebbles or boulders. The chemistry of this action I am not at present able to discuss, but the subject is one of considerable interest. It is also a proof that siliceous rocks are dissolvable by Nature's chemical agents, so that it is unnecessary to assume, as some do, that all the secondary silica binding the grains of the Triassic Sandstones has been derived from the decomposition of Felspar.*

Since this was written Mr. P. Holland, F.C.S., has, at the instance of Mr. E. Dickson, kindly made an analysis of one of the indented pebbles. I give it here together with Mr. Holland's observations thereon:—

"Analysis of an indented pebble from Stile Cop gravel pit, near Rugeley:—

SiO	79·26
$Al_2O_3 + TiO_2$	9·60
Fe_2O_3	4·80
MnO	0·08
CaO	0·22
MgO	0·97
K_2O	2·23
Na_2O	0·19
Combined Water	2·79
	100·14

* Dr. Ricketts in his paper, "On Indented Pebbles in the Bunter Sandstone near Prescot" (Proc. L'pool Geol. Soc., 1883-4, p. 447), seemingly adopts Ramsay's view, that the indents are the effect of mechanical pressure alone, and that the vertical pile of strata formerly above the beds produced lateral as well as downward pressure. I think very little of the latter could be obtained in this way. Experience with very deep corn bins teaches us that the lateral pressure on the sides does not increase after a certain depth is passed.

The major portion of the silica present in the pebble exists as quartzose sand.

A weighed portion of the finely powdered pebble when treated with sulphuric acid yielded 11·7 per cent. of alumina + oxide of iron to this reagent, or in other words over 81 per cent. of the total of these bases present in the pebble, thus showing the highly argillaceous character of the pebble.

Calculating the percentages of the potash and soda into their respective felspars, orthoclose, and albite, we have 13·18 per cent. of the former and 1·6 per cent. of the latter in a more or less decomposed state.

As regards the pitting observable on the surface of the pebble, the theory that this has been caused by the solvent effect of water retained by capillary attraction at opposed surfaces of pebbles is supported in my opinion by the chemical composition of the rock. The pitting would also be assisted by the pressure of one pebble on another."

In a conversation I had with Mr. Norman Tate, F.C.S., F.G.S., to whom I shewed one of the pitted pebbles, he said that he had little doubt that I was correct in my view, and that the pittings were due to chemical actions.

I have now imparted to you much of the information picked up in our very pleasant trip, and I trust that what the paper contains may be of some use to others exploring this strangely little known but interesting region.

GLOMERATE

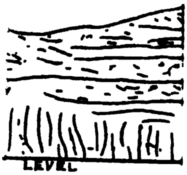


Fig. 3. G

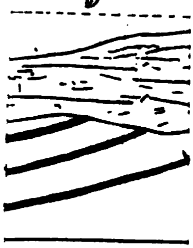
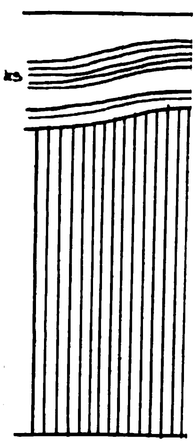


Fig.



APPENDIX.

TRIASSIC CONGLOMERATE—CANNOCK CHASE.

Description of Boulders, Pebbles, &c.

1.—Very hard, fine, close-grained, light-brown grit boulder, 7¾ in. by 6 in. by 4 in., well rounded, covered over with many pit-markings from ¾ in. diameter to ⅛ in. These cup-like depressions take the form of the pebbles that made them. What I believe to be the under side of the stone is free from these depressions. There are a good many little pebbles cemented to the stone in a sort of conglomerate of sand, which does not effervesce with acid. It must be siliceous cement (from Stile Cop).

2.—Purple-coloured quartzite boulder, 5¾ in. by 4½ in. by 3 in., ovoidal, very rounded, covered with slight depressions of a less decided type than the preceding. The inside surface of these cups is of a light grey colour, and they are confined mostly to one side (Stile Cop).

3.—Hard, fine-grained, dark-brown grit boulder, full of joint planes, on three of which it has split; these broken joints are covered with ferric oxide. The other surfaces are water-worn and deeply pitted. Some of the little quartzite pebbles are broken off, and their remains, cemented in, fill the depressions. Sand and fine gravel adherent in places like No. 1 (Stile Cop).

4.—Piece of Conglomerate, consisting of quartzite and white quartz pebbles in a matrix of sand, cemented with a calcareous cement (Moores Gorse).

5.—Pebble of compact grey limestone, 3 in. diameter, two large depressions where other pebbles have been in contact. Has a coating of sand in calcareous cement. Looks ridiculously like an owl's face.

6.—Fragment of brown sandstone pebble with casts of fossils, 3½ in. by 2 in. by 1½ in., originally about 4 in. diameter discoidal. Dr. Callaway determines the fossils as follows:—*Atrypa reticularis*, *Leptocœlia* (*Atrypa*) *hemisphærica*, *Pentamerus* sp., imperfect but perhaps *P. oblongus*, *Orthis elegantula*, *Favosites fibrosus*, a discoid coral with large tubes, tail of a trilobite—perhaps *Proetus* or *Phacops*—Crinoidal remains, and some other indeterminable fragments. Dr. Callaway adds: "This assemblage is not absolutely decisive, but the probabilities are strongly in favour of *Upper Llandovery*. The rock is a brown sandstone, such as is common in the Llandovery. The pebble has most likely come from the region west of the Severn" (near Milford).

6*a* and 6*b*.—Collected by Mr. Beasley. 6*a* (Stile Cop), is a grit with *Strophomena rhomboidalis*, probably Ordovician, west of Severn area. 6*b* is Upper Llandovery, much like No. 6. *Pentamerus*, *Atrypa* (near Milford).

7.—Fragment of well rounded boulder of grey quartzite, very distinctly banded in laminæ.

8.—Pebble of quartzite (Satnall).

9.—Very highly.polished jasper pebble (Satnall).

10.—Red jasper pebble, 1¼in. diameter, very polished.

11.—Pebble of Lydian Stone, ⅞in. diameter, highly polished.

12.—Boulder, 6½in. by 4in. by 2in., irregular in shape but polished (volcanic breccia?) (Satnall).

13.— Dark quartzite pebble, almost black (Moores Gorse).

14.—Grey quartzite pebble, traversed with quartz vein, rough surface from decomposition of the granules (Moores Gorse).

15.—Felsite pebble, banded red and white, has undergone much change, small, with crystals of quartz on walls (Moores Gorse).

16. –Pebble of rose-coloured quartzite.

17.—Pebble of highly indurated fine grained yellowish-green sandstone, apparently composed of grains of quartz and felspar.

18.—Pebble, 1½in. diameter, originally discoidal in shape, covered all over with deep cup-like depressions, often partly intersecting—one large flat depression, evidently made by contact with another pebble, and covered over with a mosaic of rose-coloured and clear quartz The structure appears curvilinear flaky (flow structure?)—is it a banded rhyolite? (Satnall).

19.—Pebble of carboniferous sandstone (millstone grit) Trias (Hednesford).

THE BUNTER CONGLOMERATE, NEAR CHEADLE, STAFFORDSHIRE.

By H. C. Beasley.

After the account of these beds in the Cannock Chase district, by Mr. Reade, it may perhaps be of interest to the Society if I describe them, as seen in a district lying about fifteen miles to the north, in August last.

Callow Hill, two miles from Cheadle, on the road to Blyth Bridge. Some gravel pits, on the top of the hill behind the farm, give some good sections of these beds, about 12 feet vertical being exposed. They resemble the beds at Cannock Chase, having just sufficient coherence to stand in a vertical face. There are a few patches of sand, and the gravel is slightly current bedded. The pebbles are, on the whole, slightly smaller. I found one of Calcareous grit, containing organic remains, apparently fragments of some Cephalopod.

Cheadle.—At the top of the hill on the side of which the town is built, are some gravel pits which show the following section :—

Surface soil	0ft. 9in.
Gravel beds with layers of sand	3ft. 6in.
Soft white sandstone, with quartz, &c., pebbles	8ft. 6in.
Gravel current bedded (base not seen)	5ft. 0in.

The gravel is similar to that at Callow Hill; the white sandstone is somewhat friable.

Between Cheadle and Tean there is a roadside section of the pebble beds, which there resemble the pebble beds of our own district.

The Conglomerate occupies the upper part of the hills that surround Cheadle, and rests directly on the coal measures; and the line of junction may be readily traced at a distance by the difference of the surface contour, the Conglomerate being deeply cut into by sub-aërial agency. The difference of vegetation is also striking, the green fields of the Coal-measures giving way at once to heather, bracken, and pine trees.

ALTON, about five miles from Cheadle. The Keuper Sandstone of the craggy escarpments that render the valley of the Churnet here so picturesque, rest, according to Mr. Hull,* upon the pebble beds, without the intervention of the Upper Bunter. The rock underlying the Keuper is a soft red sandstone, with a few pebbles. Above 30 feet is exposed on the road from the upper part of the village to the lower.

Between Alton and Oakamore, a couple of miles higher up the valley, after passing a considerable fault, there are several roadside sections of the gravel beds which maintain much the same character as at Cheadle and Callow Hill, and in one place, about 12 feet of gravel is seen interposed between beds of soft sandstone, with few pebbles, like those seen underlying the Keuper at Alton village.

* Triassic and Permian Rocks of the Midland Counties of England, pp. 92 and 93.

ON SOME FAULTS EXPOSED IN A QUARRY NEAR THINGWALL MILL.

By Joseph Lomas, Assoc. R.C.S.

Thingwall Mill forms a prominent feature in the landscape. It is visible from a great many points in the Central and Northern parts of Wirral, and is on the crest of an isolated hill which slopes rapidly Eastwards and Southwards towards the Prenton Brook, and more gently in other directions.

The hill undoubtedly owes its origin to an outlier of Keuper Sandstone (*f. 4* of the Survey), which has been faulted down into the surrounding Upper Bunter (*f. 3*).

According to the Survey Map, two isolated portions of Keuper exist, the Northern and larger portion having a greatest length of about half a mile, along the line of fault, and about 200 yards wide at its greatest extension, opposite the mill.

The Southern patch is about half these dimensions.

The quarry has been excavated in the Northern patch. It is about 80 yards S.W. of the mill, and a Survey Mark on the N.W. side gives an altitude of 244·8 feet.

It is now about twelve years since the quarry was worked. The beds exposed cannot be very far from the base of the Keuper, though I do not think the actual base is seen.

I am informed, however, that in sinking a well at Thingwall Hall, only a few yards distant, 85 feet of hard white sandstone were pierced, and then 12 feet of

soft red sandstone. It is probable that the soft red sandstone represents the Bunter, and the hard rock above the Keuper Sandstone.

As the beds dip S.W., and the Quarry is S.W. of the Hall, the base of the Keuper would be at a greater depth from the surface there, and the land rising towards the quarry, the amount would be increased. But the amount of faulting which has taken place renders it unsafe to correlate even over a short distance.

The quarry is rudely rectangular in shape. The West face is almost straight, and consists of Bunter Sandstone, the Keuper having been worked up to the fault.

The N. and S. faces are more irregular, and consist of Keuper Sandstone, often containing quartz pebbles, and bands or balls of Fuller's Earth. The other face is largely obscured by *débris* which has been thrown up against it, and the floor of the quarry is, for the most part, covered with gorse bushes.

There is a flank exposure of the main fault (8) of about 260 feet. It has a general direction of 5 degrees E. of N., but curves somewhat about the middle. Nowhere out of the quarry is it now seen, but I noticed fault rock in the direct line of fault in the smaller tract of Keuper to the South. It extends Northwards into Arrowe Park, but is not visible at present. A cutting is now exposed within a few yards of the line of fault, but consists of soft Bunter. It is a reversed fault, and the upper portion hangs over the quarry. The hade is 20 degrees W. The throw could not be determined.

Beginning at the most Northerly corner at the point B, and going Eastwards round the quarry, we first find a mass of compact sandstone, with few joints, forming

a cliff 35 feet high. This is cut off by a fault at a distance of 28 feet from B. The fault (9) has a general N. and S. direction, a hade of 25 degrees E., and the slickensides show that the movement has been vertical. The throw is not known, but must be over 30 feet. The beds following consist of a whitish sandstone, with several bands of platy sandstone interbedded. At a distance of 18 feet these are terminated by a fault (10), having a direction a little W. of N., a hade of 15 degrees W., and slickensides making an angle of 45 degrees.

At the same point another fault occurs, direction nearly E. and W. It has a horizontally slickensided face, and when projected is seen to correspond with a fault which abuts on the main fault, 24 feet S. of B.

Succeeding is an inverted wedge-shaped mass bounded after 24 feet by another fault (12), with a hade of 35 degrees N.W. Instead of the ordinary slickensides it is grooved or fluted, each groove being as much as an inch across, and inclined 30 degrees from vertical.

The bed beyond contains large nodules of Fuller's Earth, and forms a wedge-shaped mass when cut off by the next fault (13). It is also wedge-shaped horizontally, and the two faults last mentioned meet a short distance from the face of the quarry. Fault (13) has a direction E. and W. and a hade of 30 degrees S.; slickensides, vertical.

18 feet further E. another fault is seen (14), having a direction about N. and S.; a hade 19 degrees W. It is vertically slickensided.

After another 39 feet S.E. a horizontally slickensided fault occurs (15); the face has a wonderfully high polish, and hades 12 degrees N. It is seen on the floor of the

quarry, and again forming the Northern boundary of a platform of rock near the main fault. The direction is a little S. of W. On a face of rock, near where the floor of the quarry rises to the surface at the East side near the road, a patch of horizontal slickensides occurs (16). It is seen again on the face of a cliff a little to the S.W., and again on the platform of rock near where the former fault strikes it. The direction of the fault is generally E. and W., but it curves pretty sharply in the middle of the quarry.

Just entering the passage from the quarry another fault (17) is exposed on the left hand side, direction N. and S., hade almost vertical, slickensides vertical. The amount of throw can be ascertained in this case, as a clay band is seen to be displaced 1 foot 9 inches.

A little distance towards the S. the passage is crossed by a fault (1) with a direction E. and W., hade 5 degrees S., and striæ 10° E.

Returning into the quarry and still pursuing our path round, we come on a fault (2) 43 feet W. of A., hade 26 degrees W., slickensides vertical, direction about N. and S.

11 feet further West is another fault (3), hade 19 degrees W. It almost corresponds in hade and direction with one on the opposite face (14).

On the S. face just before the main fault is reached, a beautiful and extensive slickensided surface (4) is exposed. It curves considerably, but has a general direction E. and W., a hade of 30 degrees S., a throw of 4 inches, shown by the clay bands, and vertical slickensides.

The direction and hade correspond exactly with No. 13, exposed on the opposite side of the quarry; but as

one is almost due N. of the other, it is not probable that they are connected.

In the corner a horizontally slickensided face (5) occurs, having a general E. and W. direction. It is somewhat curved.

At places along the main fault pieces of unworked Keuper have been left, and in one, 80 feet from B, a fault (6) is seen having a general direction of about S.W., slickensided obliquely, with grooves 20 degrees from the vertical. It may be connected with fault No. 12.

A fault (7) is seen a little distance N. of 6. The hade is 20 degrees N., and the striations are 42 degrees from the horizontal dipping Eastwards.

On the floor of the quarry there is a low platform of rock (shaded in the plan), bounded on the N. by fault (15), and extending towards A. The surface is planed and striated. It dips with the Keuper, 10 degrees S.W., and the striæ run S.E.

Another striated surface is seen near the N.E. side of the quarry reaching up to the cliffs, and here the striæ run under the cliffs in such a way as to preclude any possibility of their having been formed during quarrying operations. The striæ in the two cases are in the same direction. The slope of one surface projected exactly corresponds with the other, so they have undoubtedly at one time been continuous.

The faults may be divided into three classes—

1. Those having a general N. and S. direction, which all hade W. like the main fault, except No. 9, and all have vertical slickensides.

2. Those bearing approximately E. and W. In all cases they are either horizontally slickensided, or else they have little or no throw. This confirms the theory lately advanced in a paper read before this society on an E. and W. fault at West Kirby.

3. Those having a bearing other than N. and S. or E. and W., and in every case but one the striæ of the slickensides are inclined.

The striæ on the rock surfaces on the base of the quarry I should be inclined to regard as the slipping surface between beds affected by horizontal faults.

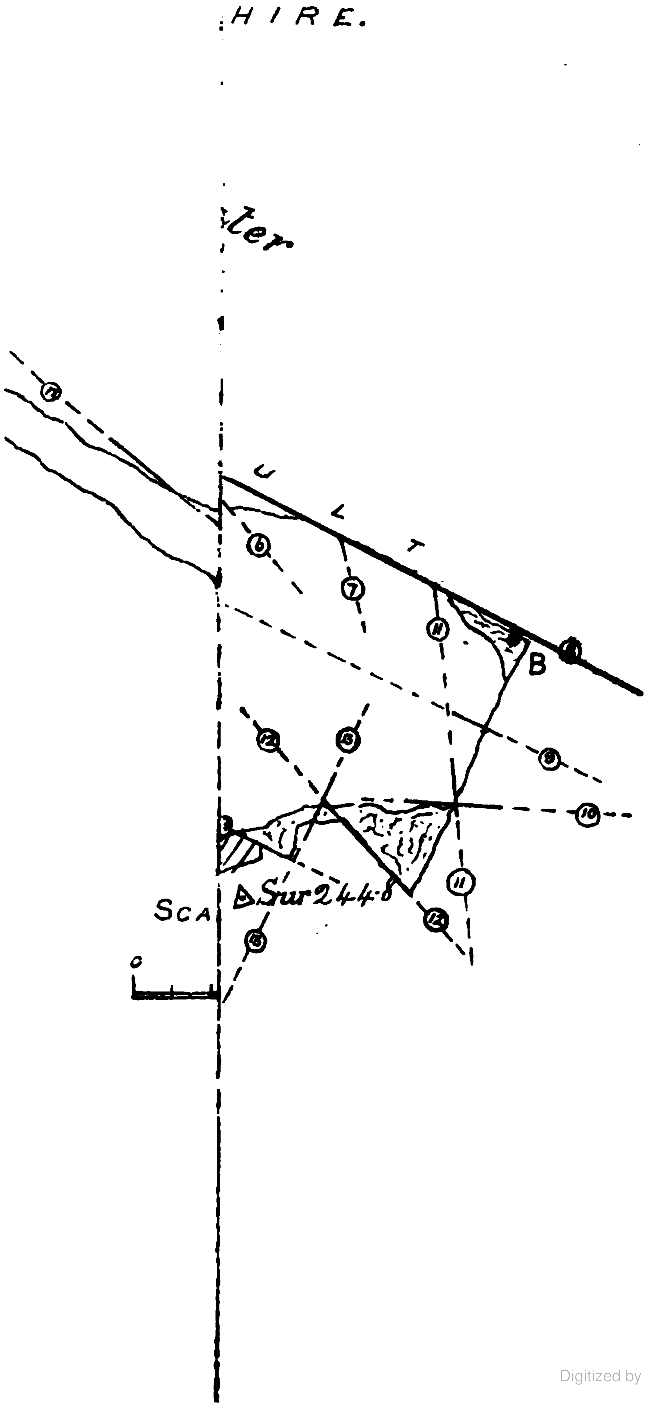
A horizontal movement along a curved fault must result in lateral motion of one or both rock masses in contact. Thus fault No. 16 may have caused the horizontal movement in the cases mentioned.

I have not been able to correlate all the faults exposed with others. The floor of the quarry is covered at so many points by débris and vegetation, and they cannot be traced.

Except in a few cases, where one fault is cut off by another, the order of faulting cannot be ascertained.

I am greatly indebted to several of my pupils for the assistance I have received in working out the details of faults, and more especially to Lieut. A. R. Dwerryhouse, who has constructed a model of the quarry on the scale of 10 feet to an inch,* and prepared plans and elevations of the various faces, and to Dr. Grossmann and Mr. Rock for the pains they have taken in photographing the quarry.

* It is now at University College, where it can be seen by anyone interested.


HIRE.
ter
ULT
B
Sur 244·8
SCA

FURTHER NOTES ON THE DEEP DALE BONE CAVE, NEAR BUXTON.

By J. J. Fitzpatrick.

In a paper read before this Society, on April 15th, 1890,* I called attention to the discovery of a bone cave at Deep Dale, a rocky gorge in the Carboniferous Limestone, about three miles E.S.E. of Buxton, and gave an account of the various objects of interest that had been discovered up to that time. This was the first communication made to a scientific society in reference to the discovery.

During the past two years Mr. Wm. Millett, of Buxton, the youthful discoverer of the bone cave, has carried on his investigations in as systematic a manner as possible, and many new objects of interest have been found in the cave, and in the "kitchen midden," or refuse heap at the entrance to it.

The following amongst other objects have been discovered in the latter by Mr. Millett :—Bones of the horse, stag, Celtic shorthorn (*Bos longifrons*), dog, pig, sheep, goat, wild boar, and numerous teeth of the Celtic shorthorn. Mr. Robert Millett, father of the young cave hunter, found amongst other objects, a whetstone, the lower jawbone of the Celtic shorthorn (*Bos longifrons*), three flint flakes, and some human molar teeth. This "kitchen midden" was 3 feet in thickness at the top near the entrance to the cave, and extended 10 feet on each side of the entrance, and down to the stream at the

* Proceedings of the Liverpool Geological Society, vol. vi.—p. 200.

bottom of the dale for 60 feet, where there were found charred branches of oak, pine, birch, and hazel. In the "kitchen midden," which was 50 feet in its widest part, there were found hundreds of fragments of pottery, including Samian ware, pseudo-Samian ware, Romano-British ware, chocolate, black, and grey wares, decorated with herring bones, zig-zag lines, dots, and various patterns. Female ornaments were plentiful, including fibulæ, earrings, brooches and rings; also coins of the Roman Emperor Claudius, who came to Britain in the year 43 A.D. A piece of bronze with Celtic pattern, as shown in Professor Boyd Dawkin's "Early Man in Britain," teeth of the Celtic shorthorn (*Bos longifrons*), and of the wolf. Two flint arrowheads were found below the refuse at the bottom of the "midden."

Owing to the publicity given in the Derbyshire newspapers to the discoveries, a large number of persons visited the cave from curiosity, in search of specimens of geological and archæological interest. Most of these visitors gave no attention to working systematically and in the interest of scientific research, and it was therefore decided by the owner of the cave, at the request of the Derbyshire Archæological and Natural History Society, that no person should be allowed to visit it unless by special permission. Mr. Wm. Millett, who has on many occasions been assisted in the work of exploration by his father, Mr. Robert Millett, has access whenever he desires. The members of this Derbyshire scientific society have been authorized to protect the cave as far as possible, and have given much attention to the discoveries that have been made in and about it.

In my previous paper, I described a section made in the floor of the second chamber of the cave, where a hole

eight feet in depth was dug. The beds, in descending order, are:—The upper bed, three feet in thickness, composed of dark clay, with angular fragments of limestone, the highest part of which forms the floor of the cave.

The second bed, consisting of broken fragments of stalagmite, limestone, and gravel, is from 6 to 18 inches in thickness. The human jaw-bone was found in this bed. The third bed, the thickness of which has not been ascertained, has been examined to a depth of about four feet, and consists of a stiff yellow clay, containing large pebbles, some of which had evidently been used as hammers, two of them being pointed at one end. These are Neolithic stone celts.

One of my chief reasons for writing this short paper is to describe, amongst other objects of interest, a lower human jaw-bone, which I have the pleasure of exhibiting this evening; the discovery of which, as I have already stated, was mentioned in my previous paper. In that communication I described many interesting objects which clearly indicated the various stages of the cave's occupation by man, and endeavoured to show that for ages it was inhabited by him. This jaw-bone is the most interesting object in connection with cave-dwelling man that has been found in the cave. It possesses twelve teeth, with the enamel and dentine in an admirable state of preservation. There were originally fourteen teeth, the two "wisdom teeth" not having developed at the time of the death of the person to whom the jaw-bone belonged. When Mr. Millett found it, several of the teeth were out, lying loose in the clay close to it. A central incisor and a lateral are missing.

At my request, Professor Herdman, F.R.S., very

kindly asked Dr. R. Hanitsch, Demonstrator of Zoology, at University College, Liverpool, to give the following four measurements of the jaw-bone :—

1. Width from middle of right to that of left Condyle, 9·7 cm. $=3\frac{13}{16}$ inches.
2. Width from right to left Coronoid process, 9·4 cm.$=3\frac{11}{16}$ inches.
3. Length of Mandibles along median basal plane, 10·6 c.m. $=4\frac{3}{16}$ inches.
4. Angle of Mandibles.$=58^\circ$.

The mark of the spear or weapon which gave a terrible blow, perhaps the death wound, and which penetrated deeply into the bone in a slanting direction, with an upward inclination, is distinctly to be seen, showing that the blow was struck from behind. The exact position in which it was found is 124 feet from the entrance to the cave, in the centre of the second chamber, which in that part is 18 feet in width. When found it was in an upright position, with the chin towards the entrance, at a depth of 3 feet 6 inches below the floor of the cave. The jaw-bone was embedded in gravel and loose stones, with thin layers of hard, crystalline stalagmite 6 inches above it. No doubt its excellent state of preservation is owing to the protection afforded by these layers of stalagmite.

Overlying the bed in which the jaw was found there was a bed of clay 3 feet in thickness, the upper part of which contained charcoal, and burnt stones, forming the floor of the cave. The position in which the jaw was found, and the surrounding conditions, indicated that in all probability it had been embedded for a great period of time.

The various objects which I am exhibiting, and others mentioned in my previous paper, show that the cave was

occupied from the earliest times. The first dweller in the cave was evidently Palæolithic man. He was followed by Neolithic man, then came the Celtic people, who drove the small dark Iberian, or Neolithic aborigines to the western and hilly parts of Britain. These Celts were in their turn dispossessed by the Romans, and Britain then became a Roman Province. Thus there have been many changes in the cave-dwellers of Deep Dale. In all probability the last cave-dwellers were the Romano-British who were driven by the Picts and Scots to shelter in the hills and caves of this country.

Amongst other objects of interest which I am exhibiting is a small bronze box, found in the second chamber of the cave in what Mr. Millett calls the Romano-British bed. The box is $1\frac{1}{8}$ in. long, $\frac{7}{8}$ in. broad, and $\frac{1}{2}$ in. in depth. It weighs five drachms, three scruples, and opens by a lid, on iron hinges, lengthways. The lid is moulded with the raised zig-zag pattern, so common in Roman ornamentation, the hollow parts being let in with red and green enamel. The sides are perforated with a small hole in each of the bottom corners, and round all the holes there is a hollow ring. These holes were, when the box was found, stopped with red and green enamel. When opened by Mr. Millett the box was filled with burnt grey ashes, supposed to be the ashes of a cremated person, as cremation was carried on in Roman Britain. The box was found in the second chamber, a few inches below the floor of the cave.

The flint and strike-lights were found near the entrance to the cave in stalagmite and charcoal, one foot below the surface. The flint flake was found near the same place.

In my former paper I stated that the following mammalian remains were found by Mr. Millett, in the lower chambers of the cave:—A skull of the brown bear (*Ursus arctos*), a skull of the Celtic shorthorn (*Bos longifrons*), teeth of the reindeer (*Cervus tarandus*), and of the red deer (*Cervus elaphus*), part of the skull of the wild boar (*Sus scrofa*), and some human bones. These remains are now in the museum, at the town hall, Buxton. Up to the present time no addition of interest has been made to this list.

In the same paper I also gave a list of the cave fauna of Derbyshire.

I have to cordially thank Mr. Millett for his kindness in giving me so many objects of interest to illustrate this paper. The plans and drawings are well executed by him, and he has furnished me with a great deal of the information, which I have placed before this Society, in connection with the Deep Dale Bone Cave.

REPORT OF THE FIELD MEETING AT SETTLE, MAY, 1891.

During Whitsuntide, 1891, a Field Meeting of the Society was held at Settle, the Lion Hotel being the headquarters. The first excursion was to Horton in Ribblesdale. From the station platform at Settle the position of the Great Craven Fault, by which the Millstone Grit has there been let down to a level with the Carboniferous Limestone, was pointed out. As the train passed northwards the situation of a secondary fault (the North Craven Fault) was indicated.

Having arrived at Horton, and walking towards Beecroft limestone quarry, attention was directed to the railway cutting a quarter of a mile south of the station, where the Lower Silurian rocks are almost buried in a moraine accumulation; their surface is smoothed and covered with striæ, having a north and south direction, being that of the Ribble Valley; another glaciated surface, with striæ in the same direction, occurs on the limestone at the southern extremity of Beecroft Quarry.

A bed, about ten or eleven feet thick, of rounded Silurian Pebbles is seen at the entrance to the quarry, the lower portion iron-stained of a red colour, but the upper is grey. It forms the basement bed of the Carboniferous Limestone. Beds of conglomerate so situated were formerly referred to the old Red Sandstone formation, with which they have no connection.

Above these basement beds the Carboniferous Limestone is black, as if at the time of its deposition the water held in suspension large quantities of carbonaceous matter, in a manner similar to moss water. It is very probable that there may have been in the vicinity at the time a considerable amount of vegetation; this is corroborated by the termination of this black limestone in a bed of coal from half to three inches thick. Immediately above the coal the limestone is much lighter in appearance, and high up becomes white.

Passing over to the opposite side of the valley at Brackenbottom, streams were seen issuing from beneath horizontal beds of limestone; flowing at Douk Ghyll over basset edges of Lower Silurian rocks. The lower beds of Carboniferous Limestone are here very impure; one specimen contained about half its weight of Silurian fragments of a size which may be designated as grit. The Lower Silurians dip S.S.W. down the valley. Their geological age is determined by their fossil contents; a few species of Brachiopoda were obtained such as *Leptæna* sp., *Orthis vespertilio*, O. *Actoniæ*, &c., all indicative of the Bala or Coniston Limestone formation. Along the road towards Settle many

exposures of Upper Silurians were passed, but only one locality, Studfold Quarry—was examined. The great similarity, or rather identity, of these rocks with the flagstones and slates of Llangollen was pointed out; their lithological characters are the same; there are nodular concretions similar to those called "apples" by the quarrymen at Llangollen; thin beds of slate occur interstratified with flags, the cleavage being confined to layers of a small fraction of an inch only in thickness; this has been called "Calf" in this district. The same fossils occur in each locality, — *Orthoceras primævum*, *Cardiola interrupta*, and graptolites.

The next excursion was to Norber Scar and Crummackdale— Leaving Settle during a heavy fall of snow we drove by Giggleswick along the direction of the Great Craven Fault and through Austwick. In consequence of the storm it was decided to pass by Cave Ha, an abode of owls, situated high up in the escarpment; beneath the opening of which the débris is full of mouse bones (described by Prof. T. McK. Hughes; Journal of Anthropological Institute, vol. iii. page 383).

Arriving at Norber attention was first directed to the immense accumulation of blocks of Silurian grit extensively spread over the surface of the Carboniferous Limestone plateau, forming the southern portion of Norber Scar, and on the Silurians situated at the base. Comparatively little alteration has taken place in these blocks; weathering having extended to only a slight depth. Some are split into two or more fragments, the detached pieces remaining in close proximity. (Some of these illustrated a paper entitled "Split and other Boulders," by C. Ricketts; Proc. Liverpool Geological Society, 1881. page 193). Many situated on the Limestone rest on pedestals, about one foot in height, left by the erosion of the unprotected Limestone; considered, and with great probability, by our friend the late Mr. D. Macintosh, that they represent the amount of erosion which has occurred to these rocks since the Glacial Period. Mr. T. Mellard Reade has referred, in Geological Magazine, July, 1891, page 291, to "the Perched Blocks at Norber," seen on this visit.

The next point of interest was the composition of the Limestone where it rests beneath Norber Scar, on the Lower Silurian slates and Limestones, and at a very short distance northward on Upper Silurian rocks. It consists of a conglomerate of rounded fragments of these strata cemented together by carbonate of lime. Many of these fragments are of large size up to three and four feet long, but higher up in the escarpment they get smaller, gradually becoming quite minute in size.

Norber Brow is the summit of a ridge extending diagonally across the valley in a south-easterly direction from Norber to the hamlet of Wharfe. The strata form an anticlinal; the fossils obtained by the writer on previous visits—*Trinucleus concentricus*, *Cybele verrucosa*, *Phacops* sp., Tentaculites, *Orthis vespertilio*, *O. Actoniæ*, with other small brachiopoda—indicate it as belonging to the Coniston or Bala Limestone series. These Lower Silurian strata extend only a little way beyond the crest of the ridge, when the Upper Silurian strata become exposed, soon taking the form of a hard compact grit similar to that of the blocks scattered over Norber. Thin bands of slate one or two inches in thickness separate these beds of "Calliard" from each other. It was suggested that from these beds, here and higher up the valley, the boulders on the summit and flanks of Norber had been derived; that during the Glacial Period, the valley being completely filled with snow, the glacier was compelled to move upwards over the ridge, carrying some of the detached fragments of rock upwards on to the limestone escarpment, and on the surface above, much higher than the source from which they were originally derived. A similar circumstance occurs near Settle; blocks of Silurian grit of a moderate size have helped to block up the entrance to Victoria Cave, and many are scattered over the limestone from which the escarpment containing the cave springs. Victoria Cave is 1,450 feet above the sea level, "the greatest elevation reached by the slaty rock being 1,160 feet" (Phillips). Some of our party examined a large Silurian block at Winskill, two miles north of Settle, having a pedestal of limestone and a gaping fissure, opposite which, lying on the ground, were two fragments just large enough to fill up the cavity (see Proc. Liverpool Geological Society, 1881, page 193, Fig. 4); close to it, the height marked upon the Ordnance map is 1,206 feet.

It is to be regretted that in consequence of delay caused by the snow storm little attention was able to be devoted to the interesting section exposed at Austwick Beck Head, where the water issues from beneath the Carboniferous Limestone. The lowest beds exposed are Lower Silurian raised at a high angle, on whose edges are deposited a conglomerate (see Geology of the Lake District, by Prof. T. McK. Hughes; Geol. Mag. 1867, p. 346), surmounted by horizontal book leaf beds of mudstone; these constitute the base of the Upper Silurian strata upon which, subsequent to the removal of immense thicknesses of over-lying strata, the Carboniferous Limestone was deposited.

C. RICKETTS.

MEMBERS

OF THE

LIVERPOOL GEOLOGICAL SOCIETY.

HONORARY MEMBERS.

WILLIAM BRYHAM, Wigan.
CHAS. CALLAWAY, D.Sc., F.G.S., Wellington, Salop.
SIR ARCHIBALD GEIKIE, D.Sc., LL.D., F.R.S., London.
HENRY HICKS, F.G.S., M.R.C.S.E., London.
JOHN W. JUDD, F.R.S., F.G.S., London.

FOREIGN CORRESPONDING MEMBERS.

M. A. DAUBRÉE, Museum of Natural History, Paris.
DR. A. HEIM, University of Zurich.
MAJOR-GEN. N. VON KOKSCHAROW, Inst. of Mines, St. Petersburg.
PROF. J. VILANOVA-Y-PIERA, University of Madrid.
DR. A. F. RENARD, Museum of Natural History, Brussels.
BARON F. VON RICHTHOFEN, Berlin.
PROF. J. J. STEVENSON, University of New York.

MEMBERS.

*†BEASLEY, H. C. (*Hon. Secretary*) Prince Alfred Road, Wavertree.
*BROWN, J. CAMPBELL, Prof., D.Sc., F.C.S., 27, Abercromby Square.
*CHALMERS, F. R., 54, Park Road South, Birkenhead.
CLAGUE, D., F.G.S., 81, Lime Grove.
*CUMMING, L., M.A., 14, Bilton Road, Rugby.
DAVIES, D., 55, Berkeley Street.
*DICKSON, E., F.G.S., 30, Eastbourne Road West, Birkdale.
*ESKRIGGE, R. A., F.G.S., The Woodlands, New Brighton.
18, Hackins Hey.
FITZPATRICK, M., 62, Seel Street.
*FITZPATRICK, J. J., 62, Seel Street.
FOSTER, E., 41, Arundel Avenue, Sefton Park.
GOFFEY, T., Nicholas Road, Blundellsands.
GOODALL, W., 43, Walmer Road, Birkdale.
GORDON, A., 168, Islington.
HANCE, E. M., LL.B (*Hon. Treasurer*), Municipal Offices, Dale Street.
*HERDMAN, W. A., Prof., D.Sc., F.R.S., F.R.S.E., University College.

*HIGGINS, Rev. H. H., M.A., 29, Falkner Square.
HILL, H. ASHTON, C.E., Wallasey Gas and Water Works, Liscard.
*HEWITT, W., B.Sc., 16, Clarence Road, Birkenhead.
*HOLLAND, P., F.C.S., Euston Hotel, London.
*JEFFS, O. W., 12, Queen's Road, Rock Ferry.
KELLY, J. DUNBAR, 4, Sweeting Street.
KENNARD, J., F.R.G.S., 38, Elm Grove, Birkenhead.
KEYTE, T. S., C.E., 9, Chatham Place.
LINDSAY, R. C., B.Sc., 112, Anfield Road.
*LOMAS, J., Assoc. R.C.S., Amery Grove, Woodchurch Lane, Birkenhead.
MOORE, C. C., 125, Chester Road, Hartford, Northwich.
*MARRAT, F. P., 13, Nursery Lane, Broad Green.
MILES, C. E., 57, Willow Bank Road, Tranmere.
MILES, W. H., 9, The Woodlands, Birkenhead.
*MOORE, T. J., A.L.S., C.M.Z.S., 25, Victoria Road, Tue Brook.
Liverpool Museum.
MORTIMER, Captain, Liverpool.
*†MORTON, G. H., F.G.S., F.R.G.S.I., 209, Edge Lane.
PATERSON, J., C.E., F.G.S., Palmyra Street, Warrington.
PLANT, H. W., M.D., 57, Upper Warwick Street.
*POTTER, C., 101, Miles Street.
*†READE, T. M., C.E., F.G.S., Park Corner, Blundellsands.
Canning Chambers, South John Street.
*†RICKETTS, C., M.D., F.G.S., 19, Hamilton Square, Birkenhead.
RICHARDSON, W. A., C.E., Valley Lodge, Borough Road, Birkenhead.
ROBINSON, J. J., 36, York Road, Birkdale.
ROCK, W. H., 75, Botanic Road.
*SEMMONS, W., 29, Great St. Helens, London.
SHONE, W., F.G.S., Upton Park, Chester.
SLATER, S., 16, Hayman's Green, West Derby.
*TATE, A. NORMAN, F.I.C., F.C.S., F.G.S., 9, Hackins Hey.
*TIMMINS, A., C.E., Argyll Villa, Runcorn.
TUNSTALL, J., 45, Vine Street.
TWEMLOW, J., 1, May Street.
*WARD, T., Brookfield House, Northwich.

ASSOCIATE.

READE, MRS., Park Corner, Blundellsands.

* Have read Papers before the Society.
† Contribute annually to the Printing Fund.

CONTENTS.